Design Memorandum

TO:	**Donlin Gold**	REF:	**EN-0011186.0064**
ATTENTION:	**Mike Rieser**	DATE:	**June 12, 2015**
FROM:	**Hamish Weatherly**	PROJ. NO.	**0011186-20**
COPIES:	**James Fueg**		
SUBJECT:	**Water Resources Management Plan: Advanced Water Treatment**		

1. INTRODUCTION

BGC Engineering Inc. (BGC) was retained by Donlin Gold to conduct detailed hydrological and hydrogeological analyses in support of the Donlin Gold Project in Alaska. The results of that work were incorporated in the Plan of Operations, Water Resources Management Plan (WRMP) (SRK, 2012), which summarizes water management activities proposed for the Construction, Operations, and Closure periods of the proposed project. Review of the WRMP will be an important focus of permit development, as well as project evaluation under the National Environmental Policy Act (NEPA).

Under average precipitation conditions, the Donlin Gold project is expected to operate with a water surplus, where more water is captured than is needed for the process plant. Under these conditions, water will be treated and released to Crooked Creek. This treatment reduces the need for water retention on site. The base case assumption is that only groundwater from pit perimeter and in-pit wells would be treated and released to Crooked Creek.

Donlin Gold is also evaluating alternative water management scenarios for the treatment and discharge of excess water. One of those excess water scenarios is Alternative 5D, Option 2 Advanced Water Treatment (AWT). This memorandum discusses this alternative scenario, and provides water balance results and schematics for the Operations and Closure periods.

2. ALTERNATIVE WATER MANAGEMENT SCENARIOS

2.1. Background

Under average precipitation conditions, the project is expected to operate with a water surplus. Surplus water will ultimately be stored in the TSF pond until closure, at which point it will be pumped to the open pit. For the base case scenario (SRK, 2012; BGC, 2014b), strategies to minimize the amount of contact water (surface water or groundwater that has contacted mining infrastructure) generated at site during Construction and Operations were developed and include the following:

- A fresh water diversion dam (FWDD) in the middle reaches of American Creek (Years -1 to 1)
- Two FWDDs in the upper watershed of Anaconda Creek (Years 1 to 3)
- Diversion channels on either side of the lined Tailings Storage Facility (TSF) (Years 1 to 17)[1]
- When the combined pond volume of the Lower and Upper Contact Water Dams (CWDs) exceeds 1,216 acre-ft (1.5 Mm^3), groundwater from the dewatering wells is treated, as needed, and then discharged to Crooked Creek.

For the excess discharge scenario (Alternative 5D), an important mechanism to further reduce pond storage volumes is the additional treatment and release of:

- TSF Seepage Recovery System (SRS) water
- CWD water
- TSF water.

The treatment of pit dewatering groundwater and TSF SRS runoff is the most effective strategy to minimize the build-up of water in the TSF. Therefore, as much of these two sources of water as possible will be discharged. To build flexibility into the overall water management system, contact water reporting to the Lower and Upper CWDs and TSF water may also be treated and discharged to Crooked Creek. The objective of this flexibility is to minimize, to the extent practical, the TSF pond volumes during Operations.

Based on the groundwater quality studies for wells completed in the mineralized zone, groundwater derived from the pit perimeter and in-pit dewatering wells is expected to require treatment prior to discharge. Water reporting to the TSF SRS, TSF pond, and CWD's is also anticipated to require treatment.

Treatment and discharge of these three sources of contact water represent a deviation from the 2012 WRMP (SRK, 2012) and 2014 Interim Update (BGC, 2014b) in which only the treatment and discharge of pit dewatering groundwater was considered. There are two excess water discharge scenarios being considered under Alternative 5D: Option 1 Flow Augmentation Scenario and Option 2 Advanced Water Treatment. Additional details of these two options are discussed below.

2.2. Alternative 5D, Option 1 – Flow Augmentation Scenario

Treatment of the following sources of water is considered for the flow augmentation scenario:

[1] After Year 17, there is insufficient space for additional channel diversions.

- treatment of groundwater from in-pit and perimeter dewatering wells (i.e., pit dewatering groundwater)
- treatment of runoff and drainage collected by the TSF SRS (i.e., TSF SRS water)
- treatment of contact water impounded in the Lower and Upper CWDs, but at a maximum of 1% of the total volume being treated at any given time (i.e., CWD water).

This option includes a flow augmentation system whereby treated contact water is mixed with fresh water, sourced from the main channel of Crooked Creek in the summer and from the Snow Gulch Fresh Water Dam (FWD) reservoir in the winter, prior to discharge to Crooked Creek. In order to meet State of Alaska water quality standards for the treated water[2], the mixing ratio will be 2:1. Thus, from April to the end of October, water will be removed from Crooked Creek to an inlet pond, located near the confluence with Queen Gulch, from which it will be pumped to a mixing tank at a 2:1 ratio with the treated water. The combined water will then flow by gravity through a pipe to an outlet pond, connected by a channel to Crooked Creek.

Option 1 includes a High Density Sludge (HDS) water treatment plant (WTP), designed for a maximum capacity of 3,113 gpm (707 m^3/h). Due to potential high variation in anticipated flows to the WTP, two HDS plants were proposed to be constructed. A smaller plant would treat flows from 141 gpm (32 m^3/h) up to 660 gpm (150 m^3/h), while a larger plant (operational during high flows) would treat from 660 gpm (150 m^3/h) to a peak flow of 3,113 gpm (707 m^3/h) (Applied Water Treatment Solutions, 2014).

Additional details and water balance model (WBM) results for Option 1 are provided in BGC, 2015.

2.3. Alternative 5D, Option 2 – Advanced Water Treatment Scenario

Option 2 considers treatment of the same sources of contact water as Option 1, with the addition of a limited volume of TSF water (process water). The method of treatment differs: the water is initially treated with a high rate clarifier (HRC) and greensand filter, followed by reverse osmosis (RO) as required (Hatch, 2015a). This treatment system has an advantage over the HDS plant in that TDS and Se are not limiting factors on the source water that may be treated and the treated effluent can be released to Crooked Creek without the need for flow augmentation. A disadvantage of this system is that a brine is produced from the RO process (75% recovery), which is then returned to the internal water cycle of the mine site. Specifically, the brine would be sent directly to the process plant as a source of reclaim water for process. The brine could be pumped to the TSF, but this cycle is less efficient, as the brine would mix with the supernatant pond and eventually be used for reclaim anyway. The advanced WTP would have a maximum capacity of 4672 gpm (1061 m^3/h).

---

[2] Total dissolved solids (TDS) and selenium (Se) concentrations are limiting factors on the release of treated water for Alternative 5D, Option 1.

Additional elements of Option 2 that differ from Option 1 include:

- contact water from the CWDs would be treated at a maximum rate of 1,101 gpm (250 m^3/h)
- the storage capacity of the Upper CWD would be increased from 2,430 acre-ft (3 Mm^3) to 3,240 acre-ft (4 Mm^3)
- TSF pond water would be treated at an average rate of 132 gpm (30 m^3/h) and a maximum rate of 313 gpm (71 m^3/h)
- evaporative sprayers could be employed on the TSF to help reduce the build-up of pond volumes in excess of 5,680 acre-ft (7 Mm^3) (this measure has been incorporated in the Option 2 analysis presented in this design memorandum).

Additional details on these elements are provided below.

3. WATER RESOURCES MANAGEMENT PLAN – OPERATIONS

Under average precipitation conditions, the Donlin Gold project is expected to operate with a water surplus, where more water is retained than is needed for the process plant. Under these conditions, water will be treated and released to Crooked Creek. This treatment reduces the need for water retention on site. Elements of Option 2, Advanced Water Treatment are discussed below.

3.1. Treated Contact Water

3.1.1. Pit Dewatering Groundwater

To provide flexibility in managing the site-wide water balance, excess groundwater from the in-pit and pit perimeter dewatering wells will be treated and discharged to Crooked Creek.

Results of the latest groundwater analysis are provided in BGC (2014a) and are summarized below in Table 3-1. In previous iterations of the groundwater flow model, the hydrostratigraphy comprised three main units: alluvium adjacent to Crooked Creek, colluvium blanketing the gently sloping valley walls and valley bottoms, and undifferentiated bedrock of the Kuskokwim group zonated with depth and ground surface elevation. In the current model, bedrock within the bounds of the site geologic model (i.e., the open pit area) was delineated by formation based on the geologic model developed for the project by Donlin Gold. Results in Table 3-1 are presented for base case (i.e., best estimate), low and high hydraulic conductivity scenarios. The low and high hydraulic conductivity scenarios are decreased and increased by a factor of five from the best estimate case. Each of these hydraulic conductivity scenarios can be readily analyzed in the WBM.

Table 3-1. Groundwater inflow estimates for dewatering wells – US standard (BGC, 2014a).

Life-of-Mine Year	Base Case (gpm)			High K (gpm)			Low K (gpm)		
	Pit Perimeter	In-Pit	Total	Pit Perimeter	In-Pit	Total	Pit Perimeter	In-Pit	Total
-2	1,471	0	1,471	3,813	0	3,813	599	0	599
-1	1,369	79	1,449	3,434	123	3,558	652	44	696
1	1,127	57	1,184	3,109	84	3,192	528	31	559
2	916	476	1,391	2,312	1,369	3,681	445	229	674
3	1,479	335	1,814	4,002	1,167	5,169	696	141	837
4	1,268	295	1,563	3,738	1,101	4,839	564	119	682
5	1,145	365	1,510	3,461	1,321	4,782	493	159	652
6	1,083	339	1,422	3,395	1,290	4,685	445	132	577
7	1,057	330	1,387	3,364	1,286	4,650	423	123	546
8	982	744	1,726	2,827	2,655	5,482	401	255	656
9	1,004	621	1,625	2,800	2,452	5,253	414	203	616
10	933	669	1,603	2,681	2,567	5,248	383	229	612
11	960	625	1,585	2,703	2,505	5,209	409	203	612
12	867	1,510	2,378	2,131	4,839	6,970	374	520	894
13	885	1,171	2,056	1,990	4,095	6,085	445	414	859
14	797	1,048	1,845	1,911	3,980	5,891	396	365	762
15	753	991	1,744	1,884	3,932	5,816	374	339	713
16	942	903	1,845	2,188	3,782	5,970	489	277	766
17	863	885	1,748	2,127	3,769	5,896	440	260	700
18	823	938	1,761	2,083	3,857	5,940	414	286	700
19	797	938	1,735	2,047	3,883	5,931	396	277	674
20	810	123	933	2,527	436	2,963	383	53	436
21	859	194	1,052	2,761	656	3,417	379	92	471
22	903	211	1,114	2,963	837	3,800	370	70	440
23	929	220	1,149	3,064	867	3,932	370	66	436
24	951	216	1,167	3,126	845	3,972	370	62	431
25	57	66	123	216	304	520	9	9	18

Note: Groundwater inflow estimates end in Year 25, as ore will be sourced from the ore stockpile rather than the pit during t he last few years of mine operation

Table 3-1. Groundwater inflow estimates for dewatering wells – metric (BGC, 2014a).

Year	Base Case (m^3/h)			High K (m^3/h)			Low K (m^3/h)		
	Pit Perimeter	In-Pit	Total	Pit Perimeter	In-Pit	Total	Pit Perimeter	In-Pit	Total
-2	334	0	334	866	0	866	136	0	136
-1	311	18	329	780	28	808	148	10	158
1	256	13	269	706	19	725	120	7	127
2	208	108	316	525	311	836	101	52	153
3	336	76	412	909	265	1174	158	32	190
4	288	67	355	849	250	1099	128	27	155
5	260	83	343	786	300	1086	112	36	148
6	246	77	323	771	293	1064	101	30	131
7	240	75	315	764	292	1056	96	28	124
8	223	169	392	642	603	1245	91	58	149
9	228	141	369	636	557	1193	94	46	140
10	212	152	364	609	583	1192	87	52	139
11	218	142	360	614	569	1183	93	46	139
12	197	343	540	484	1099	1583	85	118	203
13	201	266	467	452	930	1382	101	94	195
14	181	238	419	434	904	1338	90	83	173
15	171	225	396	428	893	1321	85	77	162
16	214	205	419	497	859	1356	111	63	174
17	196	201	397	483	856	1339	100	59	159
18	187	213	400	473	876	1349	94	65	159
19	181	213	394	465	882	1347	90	63	153
20	184	28	212	574	99	673	87	12	99
21	195	44	239	627	149	776	86	21	107
22	205	48	253	673	190	863	84	16	100
23	211	50	261	696	197	893	84	15	99
24	216	49	265	710	192	902	84	14	98
25	13	15	28	49	69	118	2	2	4

Treatment and release of groundwater from the dewatering wells is not anticipated to be required on a continuous basis. Treatment would predominantly occur during the period from spring melt through late fall, when there is expected to be an excess of water in the Lower CWD and Upper CWD that is more than sufficient to meet the freshwater demand for the process plant. In contrast, during the winter months when the CWD pond volumes are typically low, the dewatering well water and SRS water would be required for process. During exceptionally dry years, the groundwater and SRS water would also potentially be used for process during the summer and fall.

3.1.2. TSF Seepage Recovery System

A seepage recovery system, consisting of a collection pond, pumping system and groundwater monitoring/collection wells, will be part of the TSF to maintain no discharge from the TSF. The SRS, located at the downstream toe of the TSF, is designed to capture potential seepage through the liner from the TSF, and groundwater and surface water that enters the TSF rock underdrains (BGC, 2011a). Previously, it was assumed that all water from the SRS would be utilized in process. For the alternative approach discussed here-in, SRS water may be treated and discharged to Crooked Creek. When fresh water availability for the process plant is low (e.g., late winter or periods of extended drought), the SRS water would also be available for use in process, rather than being treated and discharged.

There are two sources of water that report to the SRS: potential seepage from the lined TSF and a much larger volume of baseflow (surface and groundwater) that will routinely report to the TSF underdrain; each water source is discussed below.

TSF Seepage

The amount of seepage from the lined TSF is expected to be minimal, and most of the water reporting to the SRS pond will be underdrain water composed of groundwater and surface water from areas up gradient of the TSF. However, lined tailings storage facilities do leak, and there are a number of methodologies available for estimating the potential seepage flux through the liner. The seepage rate from the proposed Donlin Gold TSF for the starter and ultimate dam configurations (BGC, 2011a) was estimated using the industry standard, two dimensional (2D), finite element groundwater flow model Seep/W (Geo-Slope, 2007).

The modeling considered a cross-section running west to east through the maximum section of the dams to the eastern extent of the impoundment footprint. Best-estimate hydraulic conductivity values obtained from testing data for the bedding layer (i.e., Terrace Gravels), overburden and bedrock within the Anaconda Creek Valley were used in the simulations. Simulations to investigate model sensitivity to material input parameters were also completed and are documented in BGC (2011a). To incorporate the TSF liner in the 2D seepage analysis, the following assumptions were made:

- Typical hydraulic conductivity value for 60 mil (1.5 mm) LLDPE liner of 8.5×10^{-10} ft/d (3×10^{-15} m/s) (Schroeder, et. al., 1994).

- A 0.16 in^2 (1 cm^2) flaw per acre liner defect ratio based on recommendations by Giroud and Bonaparte (1989).
- The underlying materials (overburden and bedding materials) were assumed to have a horizontal hydraulic conductivity of 0.11 ft/d (4 x 10^{-7} m/s) and a horizontal to vertical anisotropy ratio of 4:1.

Based on these assumptions, the liner system was implemented in the seepage model as a unit 13 ft (4 m) thick with an effective soil and liner hydraulic conductivity of 2.8 x 10^{-6} ft/d (1 x 10^{-11} m/s).

Table 3-2 presents seepage estimates for the starter and ultimate configurations. The total seepage for these cases was calculated using predicted seepage per unit thickness multiplied by the saturated dam crest length and a correction factor of two-thirds.

Table 3-2. Best estimate steady-state seepage rates from the TSF, for Starter and Ultimate configuration.

Year	Tailings Elevation		Pond Elevation		Estimated Seepage Rate	
	(ft)	(m)	(ft)	(m)	(gpm)	(m^3/h)
1: Starter	561	171	561	171	1.4	0.31
27: Ultimate	830	253	827	252	17.6	4.0

To evaluate the change in estimated seepage rate from the starter to the ultimate TSF configuration, the following equation was applied (Giroud, 1997):

$$Q = 0.976\, C_{qo} \left[1 + 0.1 \left(\frac{h}{t_s}\right)^{0.95}\right] d^{0.2} h^{0.9} k_s^{0.74}\, a \qquad \text{[Eq. 1]}$$

It is important to note that Equation 1 is semi-empirical and developed for the SI system of units. In Equation 1, Q is the estimated seepage rate through the liner (m^3/s), C_{qo} is a coefficient that describes the contact between the liner and soil beneath it (C_{qo} = 0.21 for good contact, C_{qo} = 1.15 for poor contact), h is the average head on the liner (m), t_s is the thickness of liner and associated low hydraulic conductivity soil bedding layer (in this case Terrace Gravels 1 m thick), d is the assumed diameter of circular defects in the liner (0.01 m), k_s is the composite hydraulic conductivity of soil and liner (1.0 x 10^{-11} m/s), and a is the number of defects (1 defect/acre). The area of the tailings will be about 272 acres (110 ha) at Year 1 and about 2,351 acres (951 ha) at Year 27.

Using Equation 1, a base elevation of 125 m for the tailings to calculate maximum head, dividing by 2 to get average head on the liner, and assuming a conservative liner contact coefficient, C_{qo} = 1.15, seepage rates for the Starter and Ultimate configurations were calculated to be 0.31 gpm (0.07 m^3/h) and 12.7 gpm (2.88 m^3/h), respectively, which are generally consistent with the results of the 2D SEEP/W seepage modeling (Table 3-2). Using Equation 1, and accounting for the increasing liner area overlain by tailings/tailings pond with time, it was found that leakage rate increases in an approximately linear fashion. As such, a simple linear increase in seepage rate with time was calculated for the results of the 2D SEEP/W modeling (i.e., between 1.4 gpm (0.31 m^3/h) in Year 1 to 17.6 gpm (4.0 m^3/h) in Year 27). The predicted seepage rates are considered to be generally conservative estimates because they do not account for decreasing seepage due to tailings consolidation. Predicted seepage rates considered in the modified water management strategy are provided in Table 3-3.

Table 3-3. Estimated seepage rates from the TSF.

Year	Estimated Seepage Rate (gpm)	Estimated Seepage Rate (m^3/h)
2	2.0	0.45
5	3.9	0.88
10	7.0	1.6
15	10.1	2.3
20	13.2	3.0
25	16.3	3.7

Baseflows

Results from the three-dimensional (3D) numerical hydrogeologic model developed for the mine site (BGC, 2014a) were used to calculate the water flows that report to the TSF underdrain system and subsequently to the SRS. Modeling results are summarized in Table 3-4 beginning in Year 2 and then for life of mine (LOM) at five year intervals. Average underdrain flows are shown for summer (April to October) and winter (November to March) periods.

Table 3-4. Groundwater flows reporting to TSF SRS.

Year	Underdrain Inflows (gpm)		Underdrain Inflows (m^3/h)	
	Summer	Winter	Summer	Winter
2	709	492	161	112
5	1032	712	234	162
10	872	609	198	138
15	735	511	167	116
20	661	459	150	104
25	572	399	130	91

Of note is that underdrain inflows to the SRS are predicted to increase between Years 2 and 5. This increase is the result of water management. In Years 1 to 3, two FWDDs are in place in the Upper Anaconda valley (TSF North and South FWDD). These dams will be effective in limiting inflows to the underdrains. Once these structures are removed at the end of Year 3 to provide additional tailings storage area, the area contributing flows to the TSF underdrains temporarily increases.

3.1.3. Contact Water Dams

The Lower and Upper CWDs are located in American Creek with the objective of managing runoff of contact water from the waste rock facility (WRF) and open pit. The Lower CWD will receive runoff from a variety of sources:

- Surface and seepage runoff from the waste rock.
- Runoff from undisturbed ground upgradient of the waste rock.
- Surface runoff within the open pit footprint.
- Horizontal drains from the open pit.
- Runoff collected behind the ore stockpile berm.
- Runoff collected in a sediment pond downstream of the South Overburden (SOB) stockpile.

The dams are designed to store water that will be used throughout the year as a source of fresh water for the process plant. Peak runoff is limited to the spring and summer months, with negligible runoff volumes between mid-October and the beginning of April. These variable flows are in contrast to the constant fresh water demand. During the former period, runoff volumes are in excess of fresh water requirements and this excess water will be stored. The stored water will be a useful source of fresh water during the fall and winter, when inflows are minimal. Additional details of water management in the Lower and Upper CWDs is provided in SRK (2012) and BGC (2011b).

The objective of treating water from the CWDs at a maximum rate of 1101 gpm (250 m^3/h) is to build flexibility into the water management system such that TSF pond volumes are minimized to the extent practical during Operations.

3.1.4. TSF

During periods of high runoff, TSF pond volumes are predicted to rise even with treatment of the other sources of contact water. Therefore, when excess TSF pond volumes develop, TSF water will be sent to the WTP at a maximum rate of 313 gpm (71 m^3/h) where it will be blended with the other sources prior to treatment. As with the treatment of CWD water, the intent is to build flexibility into the water management system and minimize TSF pond volumes to the extent practical.

3.2. WTP Operation

It is assumed that the WTP will operate for eight (8) months of the year – from the beginning of April (start of snowmelt) through to the end of November. However, it will have the ability to operate and discharge on a year-round basis if required. Other scenarios, including Option 1 and the base case, also include the ability for year-round treatment, although in reality treatment is rarely needed beyond the end of December with any of these scenarios.

The RO plant will produce an estimated brine of 25% during Operations. During Construction, however, only the dewatering well water may require treatment. The estimated water quality of these wells is significantly better than runoff to the TSF, SRS and CWD. Therefore, during Construction it is assumed that 90% of the dewatering well water can bypass the RO stage, thereby reducing the brine production to 2.5% during this period. It is assumed that the brine is deposited in the Lower CWD for storage during the Construction period. A brine volume of 97 acre-ft (120,000 m^3) is estimated for the construction period, of which 68 acre-ft (83,500 m^3) would be deposited of in the Lower CWD. The remaining brine volume of 29 acre-ft (36,500 m^3) would be generated between October of Year -2 and March of Year -1. The deposition of this initial brine production will need to be addressed by the construction schedule.

3.3. Operational Rules

During wet years or a sequence of above average precipitation years, there is the potential for excess water to accumulate in the Upper CWD. Because this excess water is undesirable from a water management perspective, a number of operational rules were developed. These operational rules are discussed below for the base case (i.e., 2012 WRMP) and AWT scenarios.

3.3.1. Operational Rules - Base Case

Operational rules to manage CWD runoff for the base case scenario are as follows:

- When the combined Lower and Upper CWD pond volume exceeds 1,216 acre-ft (1.5 Mm^3), groundwater from the perimeter pit dewatering wells (outside or up-gradient of the mineralized areas) is treated at the current dewatering rate and then discharged to Crooked Creek.
- When the combined pond volume exceeds 2,108 acre-ft (2.6 Mm^3), the entire process water demand (fresh and non-fresh) is pumped from the Lower CWD (and Upper CWD if required) to the process plant. TSF reclaim water is not pumped to the process plant for non-fresh water needs during these periods, thus contributing to the build-up of pond volume.

There is also a requirement that the Lower CWD volume not exceed 405 acre-ft (0.5 Mm^3) for more than 5% of the time (see BGC, 2014b for details). Therefore:

- When the volume of the Lower CWD exceeds 284 acre-ft (0.35 Mm^3), contact water is pumped up to the Upper CWD at a maximum rate of 6,605 gpm (1500 m^3/h) for temporary storage.

The above operational procedures maintain maximum operational pond volumes of 811 acre-ft (1.0 Mm^3) and 2,432 acre-ft (3.0 Mm^3) for the Lower CWD and Upper CWD respectively.

3.3.2. Operational Rules – Advanced Water Treatment

Operational rules to manage CWD runoff for the AWT scenario are as follows:

- When the combined pond volume of the Lower and Upper CWDs exceeds 1,460 acre-ft (1.8 Mm^3), groundwater from the pit perimeter and in-pit dewatering wells and inflows to the SRS are treated at the current inflow rate and then discharged to Crooked Creek.
- When the combined pond volume of the Lower and Upper CWDs exceeds 1,860 acre-ft (2.3 Mm^3), CWD water is pumped to the WTP at a maximum rate of 1101 gpm (250 m^3/h) where it is combined with the other sources of water for treatment. Treatment of TSF water also commences at this time at an assumed average rate of 220 gpm (50 m^3/h).
- When the combined pond volume of the Lower and Upper CWDs exceeds 2,920 acre-ft (3.6 Mm^3), the entire process water demand (fresh and non-fresh water) and is pumped from the Lower CWD (and Upper CWD if required) to the process plant.

With these operational rules, the storage capacity of the Upper CWD is increased from 2,430 acre-ft (3 Mm^3) to 3,240 acre-ft (4 Mm^3). In deriving these operational rules and the need for an increase in storage capacity of the Upper CWD, a number of sensitivity runs were modelled with the site-wide WBM. The sensitivity runs looked at Upper CWD volumes of 2430, 3240, and 4050 acre-ft (3, 4 and 5 Mm^3), as well as CWD treatment rates of 1101, 2202, and 4403 gpm (250, 500 and 1000 m^3/h). Those sensitivity runs indicated that treatment rates in excess of 1101 gpm (250 m^3/h) and an Upper CWD storage volume in excess of 3240 acre-ft (4 Mm^3) resulted in diminishing returns with respect to minimizing TSF pond volumes at the end of Operations. Furthermore:

- there is a topographic limit to the height of the Upper CWD before saddle dams are required; and
- during periods of high runoff, inflows are sufficiently high that even a CWD treatment rate of 4403 gpm (1000 m^3/h) is unable to prevent the Upper CWD from reaching capacity. At this point, reclaim in the TSF would be shut off until volumes are manageable.

The combination of CWD treatment and increase in storage capacity of the Upper CWD will allow the mine operators to control CWD volumes more advantageously. Under the base case scenario, the combined pond volume of the Lower and Upper CWD frequently exceeds 2,108 acre-ft (2.6 Mm^3), resulting in the entire process water demand being pumped from the CWD to the Process Plant. The net effect is that TSF reclaim water is not pumped to the plant during such periods and pond volumes increase accordingly. With the increase in the Upper CWD pond volume and treatment of CWD water, the period of time in which the entire process water demand is met entirely from the CWD is significantly reduced.

A volume-elevation curve for the Upper CWD is shown in Figure 3-1. With a storage volume of 3,240 acre-ft (4 Mm^3) the dam crest would be at elevation 1130.2 ft (344.5 m), which represents a dam raise of 16.4 ft (5 m) compared to the 2,430 acre-ft (3 Mm^3) storage option.

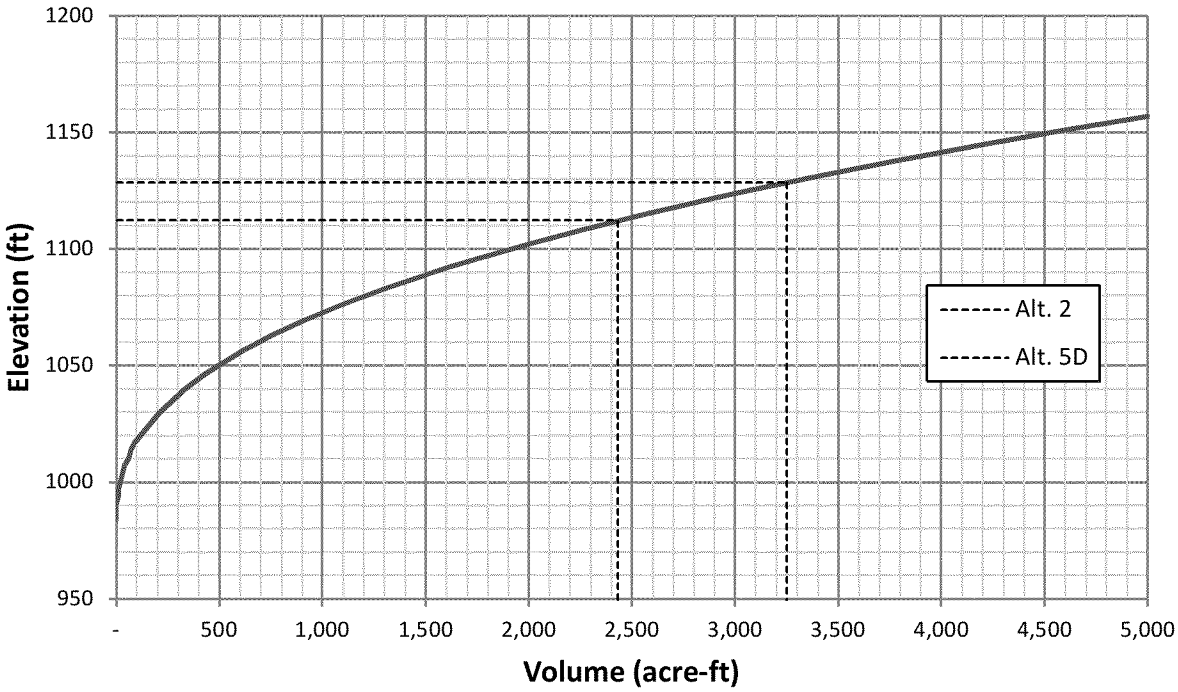


Figure 3-1. Volume-elevation curve for the Upper CWD.

3.4. TSF Enhanced Evaporation System

As well as sending a small portion of TSF pond water to the WTP, the AWT scenario also considers the deployment of an enhanced evaporation system at the TSF. This system would consist of a number of air blast evaporator units that spray water into the atmosphere to enhance evaporation. The units enhance evaporation by mechanically increasing the exposure area of the water droplets relative to the pond surface, where only the surface of the pond is exposed to the air. A key factor in this process is that droplets are suspended long enough for natural evaporation to occur. Donlin Gold employed such a system in 2013 as part of a pumping test being conducted on the floodplain adjacent to Crooked Creek. Evaporators were deployed to remove the pumped water via evaporation, rather than allowing it to discharge directly to Crooked Creek (Photo 1).

Photo 1. Evaporators deployed at Donlin in August 2013. Photo courtesy of Donlin Gold.

In evaluating the use of evaporators at Donlin, BGC assumed these units would only be employed during the late spring and summer and when TSF pond volumes exceed 6,490 acre-ft (8.0 Mm^3). A minimum TSF pond volume of 5,680 acre-ft (7.0 Mm^3) will be maintained during Operations, which represents about three months of water supply to the Process Plant. The actual number of evaporative sprayer units purchased would need to account for down-time, maintenance, and potentially variable efficiency rates.

3.5. Process Plant Water Use

As part of the AWT assessment, Hatch (2015b) has re-evaluated the fresh water demands for the process plant, as summarized in Table 3-5. With the revised evaluation, the fresh water requirement as a percentage of the total water requirement is 13.9%. This value is a significant reduction compared to earlier evaluations where the percentage was 19.3% (BGC, 2011b).

Table 3-5. Donlin Gold process rates and water requirements.

	US standard	Metric
Ore tonnage (stpd, tpd)	58,974	53,500
Tailings tonnage (stpd, tpd)	60,054	54,480
Ore moisture (gpm, m^3/h)	198	45
Tailings water (gpm, m^3/h)	17,926	4,071
Mill losses (gpm, m^3/h)	273	62
Total water requirement (gpm, m^3/h)	18,001	4,088
Minimum fresh water requirement (gpm, m^3/h)	2,501	568
Maximum reclaim (gpm, m^3/h)	15,500	3,520

[1] Ore throughput to the process plant is bulked up by 1.8% through the addition of various reagents.

4. WATER BALANCE RESULTS – OPERATIONS

As described in detail in BGC (2011b), the water balance can be evaluated with a deterministic precipitation dataset and using a stochastic WBM. Water balance results for Alternative 5D Option 2 are provided in this section.

4.1. Summary of Stochastic Water Balance Model Results

The stochastic WBM was used to determine the likely range of possible outcomes for a number of variables such as the TSF impoundment volume at the end of Operations. The 50th and 95th percentile values over the life-of-mine (LOM) are shown in Figure 4-1, and the cumulative volume over the LOM for various percentiles are shown in Table 4-1. While the stochastic WBM results show a steady increase in TSF impoundment volumes over the LOM, impoundment volumes are expected to fluctuate from year to year.

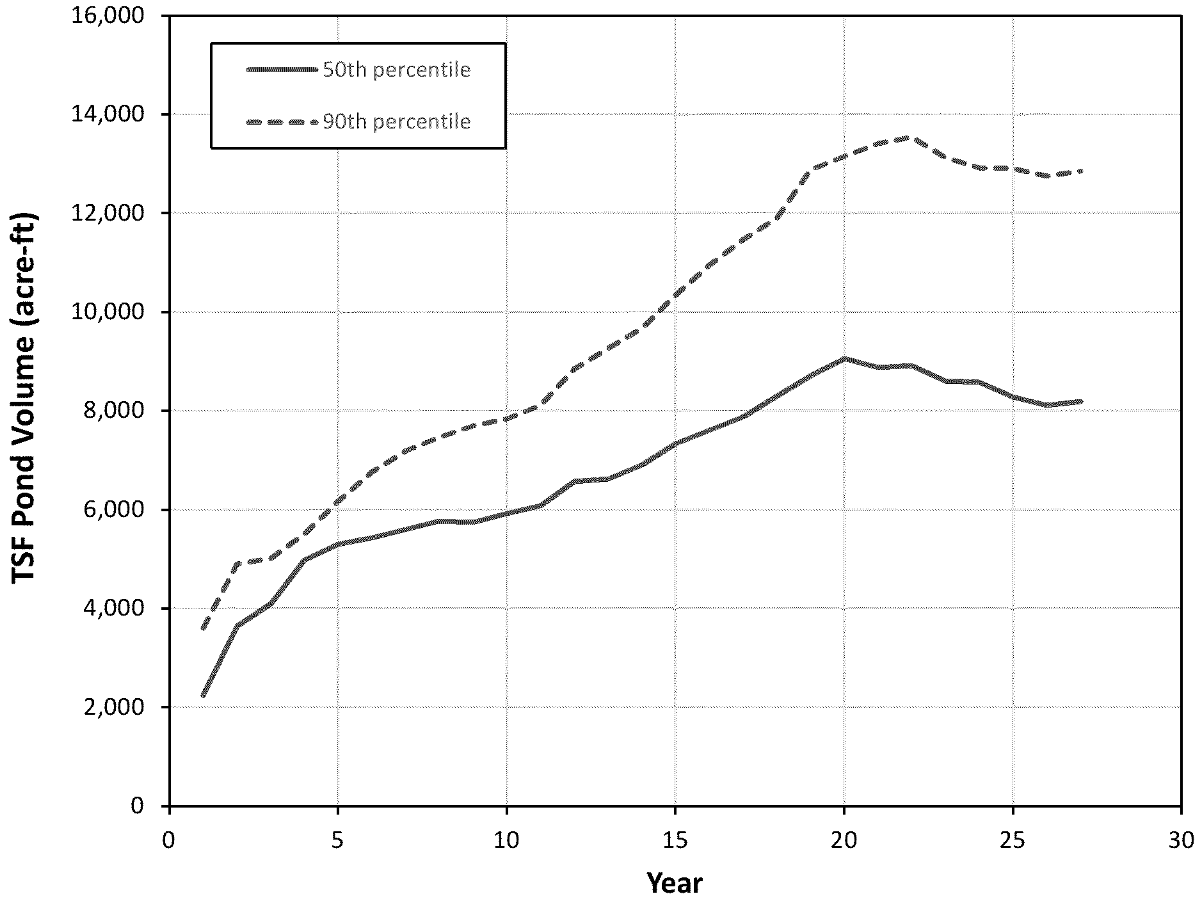


Figure 4-1. Annual TSF pond volumes over the life-of-mine using the stochastic water balance model.

Table 4-1. Summary of stochastic water balance model results – End of Operations.

Variable	Volume (acre-ft)										
	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%
TSF Impoundment Volume	6,380	6,900	7,320	7,750	8,190	8,860	9,610	10,800	12,860	14,450	18,240
Treated Water	61,620	64,720	66,820	68,430	69,940	71,140	72,490	74,580	77,020	79,550	83,500
Variable	**Volume (Mm^3)**										
	10%	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**95%**	**99%**
TSF Impoundment Volume	7.87	8.52	9.02	9.56	10.10	10.93	11.85	13.32	15.86	17.82	22.50
Treated Water	76.0	79.8	82.4	84.4	86.3	87.7	89.4	92.0	95.0	98.1	103.0

4.2. Treated Water and Effluent Discharge

Average monthly flows of water being treated (Years 1 to 24) are summarized in Table 4-2. To eliminate potential issues with operation and maintenance of the WTP during the winter months, it is assumed that treatment is restricted to the April to November period.

Table 4-2. Average monthly treatment rates by source during Operations (US standard).

Month	Treatment Rate (gpm)					
	Perimeter Pit Groundwater	In-Pit Groundwater	TSF SRS	TSF	CWD	Total
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	823	568	630	106	669	2,796
May	854	581	704	128	713	2,985
June	621	458	471	128	462	2,144
July	621	467	493	136	445	2,157
August	691	511	603	159	577	2,541
September	766	550	709	176	757	2,959
October	819	577	731	189	797	3,113
November	779	550	678	172	603	2,783
December	0	0	0	0	0	0
Average	**498**	**357**	**418**	**101**	**418**	**1,788**
Percentage	**28%**	**20%**	**23%**	**6%**	**23%**	

Table 4-2. Average monthly treatment rates by source during Operations (metric).

Month		Treatment Rate (m^3/h)				
	Perimeter Pit Groundwater	In-Pit Groundwater	TSF SRS	TSF	CWD	Total
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	187	129	143	24	152	635
May	194	132	160	29	162	678
June	141	104	107	29	105	487
July	141	106	112	31	101	490
August	157	116	137	36	131	577
September	174	125	161	40	172	672
October	186	131	166	43	181	707
November	177	125	154	39	137	632
December	0	0	0	0	0	0
Average	**113**	**81**	**95**	**23**	**95**	**406**
Percentage	**28%**	**20%**	**23%**	**6%**	**23%**	

4.3. Snow Gulch FWD

The Snow Gulch FWD is a contingency source of fresh water to the process plant during Operations. During a period of drought (a sequence of years with below average precipitation), there is the potential for there to be insufficient water to meet the process plant fresh water demand. In such an event, make-up fresh water is then obtained from the Snow Gulch FWD. With the reduced fresh water demand for the process plant (

Table 3-5, Hatch 2015b), the need for the FWD has been re-evaluated.

Simulations with the deterministic and stochastic WBM indicate that the potential demand from Snow Gulch is generally limited to the first eight years of mine life. Beyond this time frame, the Open Pit footprint has enlarged such that runoff contributions from this facility are generally sufficient to offset any fresh water deficits due to drought conditions. The simulations also indicate that the Snow Gulch make-up demand occurs in response to a series of years of below average precipitation rather than an individual year of drought.

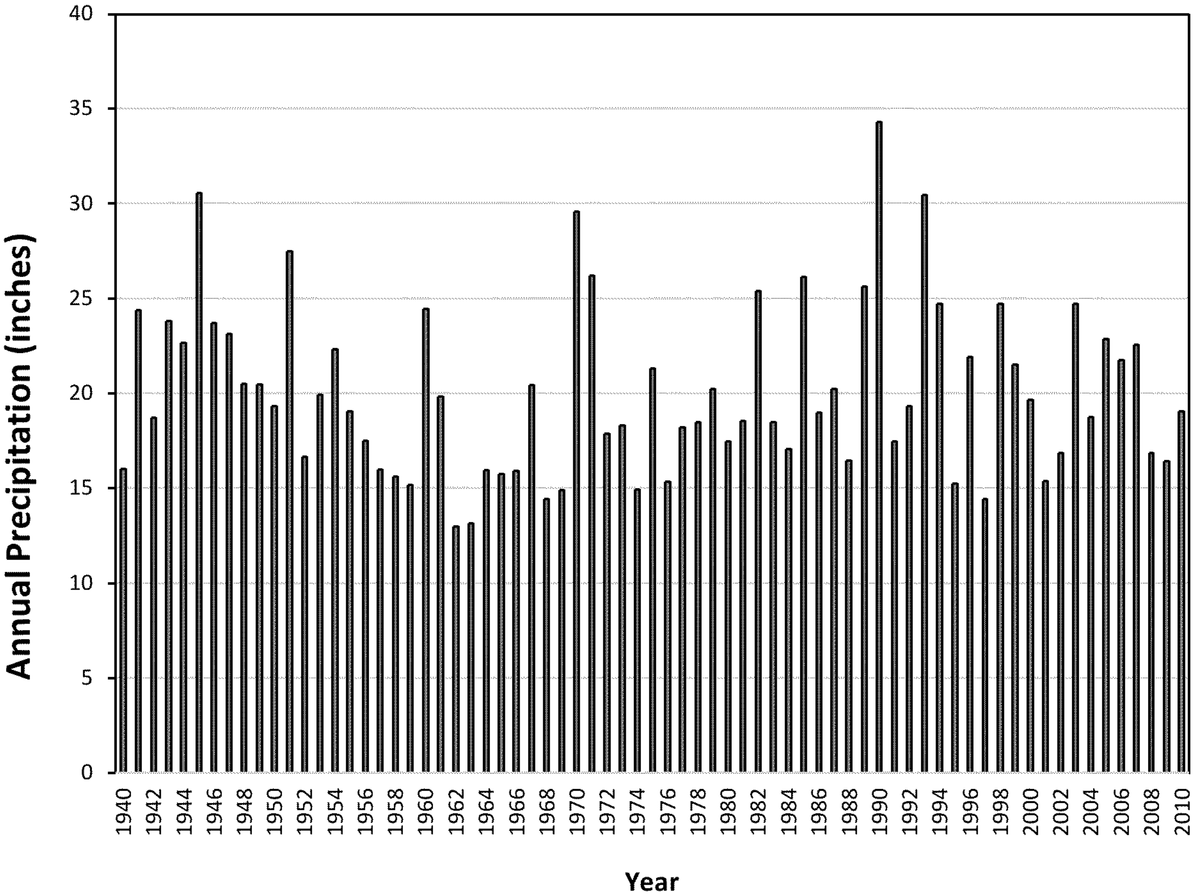


Figure 4-2. Annual precipitation at Donlin (1940-2010).

Figure 4-2 shows the average annual precipitation at Donlin for the 1940-2010 period. This synthetic dataset was developed through comparison of site data with regional climate stations (BGC, 2011b). Of note is the dry period of 1962-1966. Average annual precipitation in this period was 14.7 inches (374 mm), which is about 25% less than the long-term average of 19.6 inches (500 mm). Individual annual precipitation values are listed in Table 4-3 below along with the associated recurrence interval. The recurrence interval is expressed as a percentage. Annual precipitation at Donlin for a 100-year return period dry year has been estimated by BGC at 13.1 inches (335 mm). That return period corresponds with a recurrence interval of 99%, so out of every 100 years, 99 of them will have an annual precipitation that exceeds 13.1 inches

(335 mm). Table 4-3 indicates that the region had successive dry years (1962 and 1963) with 100-year return period annual precipitation.

Table 4-3. Annual precipitation at Donlin 1962-1966.

Year	Annual Precipitation		Recurrence Interval (%)
	(inches)	(mm)	
1962	13.0	329	99
1963	13.1	334	99
1964	16.0	405	95
1965	15.7	400	95
1966	15.9	404	95

Previous iterations of the WBM had identified this sequence of years as problematic from a drought perspective and were utilized in the sizing of the Snow Gulch FWD. Simulations with the WBM indicated that the FWD should have an operating capacity of 3,243 acre-ft (4 Mm^3) and it was designed accordingly with this storage volume (BGC, 2011b). Except when water is being withdrawn from the pond for use in process, the intent was to keep the dam at its maximum storage capacity (i.e., the spillway would be used on a near continuous basis).

With the reduced fresh water requirement for the process plant, the deterministic WBM can be used to evaluate the fresh water make-up requirements for the process plant using this sequence of dry years in the first seven years of mine life. Annual make-up fresh water volumes required for the process plant in the first eight years of mine life are summarized in Table 4-4 for calendar start dates varying from 1957 to 1963. These results indicate that the required annual make-up volume could be as high as 1,760 acre-ft (2.2 Mm^3), which represents an average annual flow of 1101 gpm (250 m^3/h).

Table 4-4. Annual make-up fresh water required for process plant during 1960's drought (US standard).

Operating Year	Fresh Water Make-Up Volume (acre-ft)						
	Calendar Year for Year 1 of Operations						
	1957	1958	1959	1960	1961	1962	1963
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	390	1320	670	20
4	150	0	240	1620	1070	360	430
5	0	280	1690	1150	410	400	300
6	0	1760	1380	560	260	460	300
7	820	1010	560	0	0	20	620
8	610	0	0	0	0	0	0

Note: Assumes a minimum pond volume of 5,680 acre -ft (7.0 Mm^3) is maintained in the TSF.

Table 4-4. Annual make-up fresh water required for process plant during 1960's drought (metric).

Operating Year	Fresh Water Make-Up Volume (Mm^3)						
	Calendar Year for Year 1 of Operations						
	1957	1958	1959	1960	1961	1962	1963
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.48	1.63	0.83	0.03
4	0.18	0.00	0.29	2.00	1.32	0.45	0.53
5	0.00	0.34	2.09	1.42	0.50	0.49	0.37
6	0.00	2.17	1.70	0.69	0.32	0.57	0.37
7	1.01	1.24	0.69	0.00	0.00	0.03	0.77
8	0.75	0.00	0.00	0.00	0.00	0.00	0.00

Note: Assumes a minimum pond volume of 5,680 acre -ft (7.0 Mm^3) is maintained in the TSF.

The results above indicate that an alternate source of fresh water would still be required for the mine, particularly in the first eight years of mine life. The results suggest that the Snow Gulch FWD storage capacity could be reduced to 2,030 acre-ft (2.5 Mm^3) or an alternative source of water could be defined. Potential sources include:

- American Creek FWDD: To limit inflows to the Lower CWD during Construction, a fresh water diversion dam (American FWDD) will be constructed upstream of the Lower CWD. Fresh water accumulating behind the American FWDD will be stored up to a maximum capacity of 867 acre-ft (1.07 Mm^3) with the excess pumped to Omega Gulch. The American FWDD will only be utilized until the process plant is at full capacity and the diverted water is then required for process (anticipated to occur by the end of Year 1). The footprint of the FWDD is also rapidly encroached upon by the waste rock storage facility (WRSF).
- TSF North and South FWDDs: During construction and the first three years of operations, two fresh water diversion dams will be maintained in Upper Anaconda: TSF North FWDD and TSF South FWDD. These diversion dams have a dual purpose. During construction, the diversion dams will be utilized as cofferdams that will facilitate construction of the TSF Starter Dam and liner placement. The dams will also minimize runoff to the TSF during initial operations. Both diversion dams will have capacity to store the 100-year return period snowmelt runoff, which is 478 acre-ft (0.59 Mm^3) for the North FWDD and 211 acre-ft (0.26 Mm^3) for the South FWDD.

Combined these three FWDDs would just about have the required storage volume to meet the maximum required make-up volume; however, the American FWDD is only operational to end of Year 1, while the TSF FWDDs are abandoned after Year 3.

It should be noted that the required make-up volumes in Table 4-4 assume that a minimum pond volume of 5,680 acre-ft (7 Mm^3) would be maintained in the TSF. If this constraint was relaxed to 2,030 acre-ft (2.5 Mm^3) for the initial years of operation, the required make-up volumes would be reduced by about 40%. The difference is that with a minimum pond volume of 5,680 acre-ft (7 Mm^3), more time is spent building up the TSF pond inventory by minimizing TSF reclaim rates and thereby resulting in an increased fresh water demand for process.

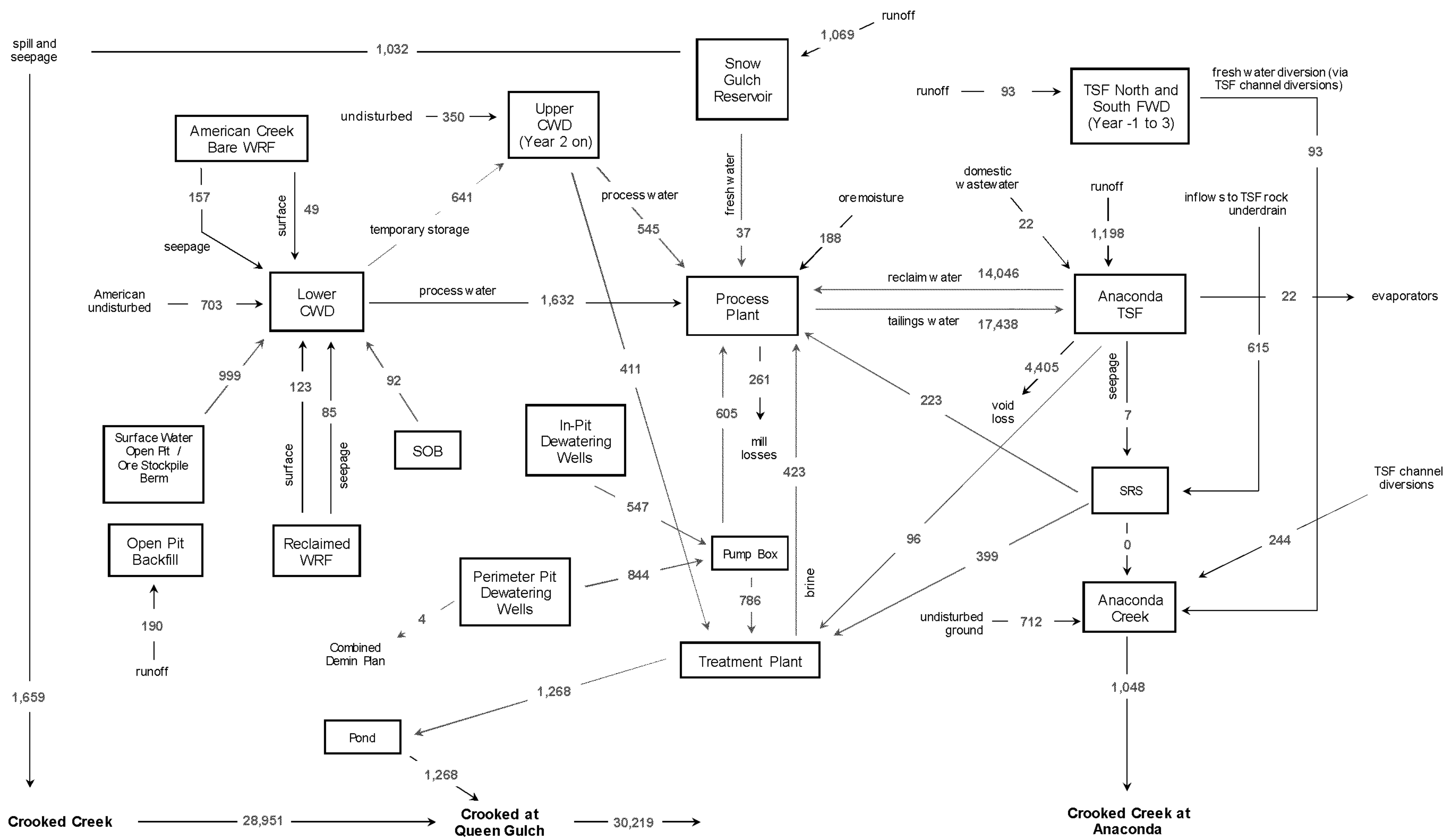
4.4. Water Balance Model Flow Schematics

Figure 4-3 shows annual average flows (gpm) for all components of the Operations water balance system based on the average precipitation scenario of the deterministic WBM. It should be noted that these values represent annual average totals, but there will be considerable variation on a weekly, monthly and annual basis. Similar schematics are shown for above average precipitation (Figure 4-4) and below average precipitation (Figure 4-5) scenarios.

Water balance schematics during Operations have also been developed at various stages of mine life. The various figures are summarized in Table 4-5. Flow rates shown in the figures represent annual averages for the 10^{th}, 50^{th} and 90^{th} percentiles at Years 2, 5, 15, and 25. Of note in Figure 4-9 is that runoff from the bare WRF is zero for Year 25. This zero flow reflects the fully reclaimed status of the WRF by this year.

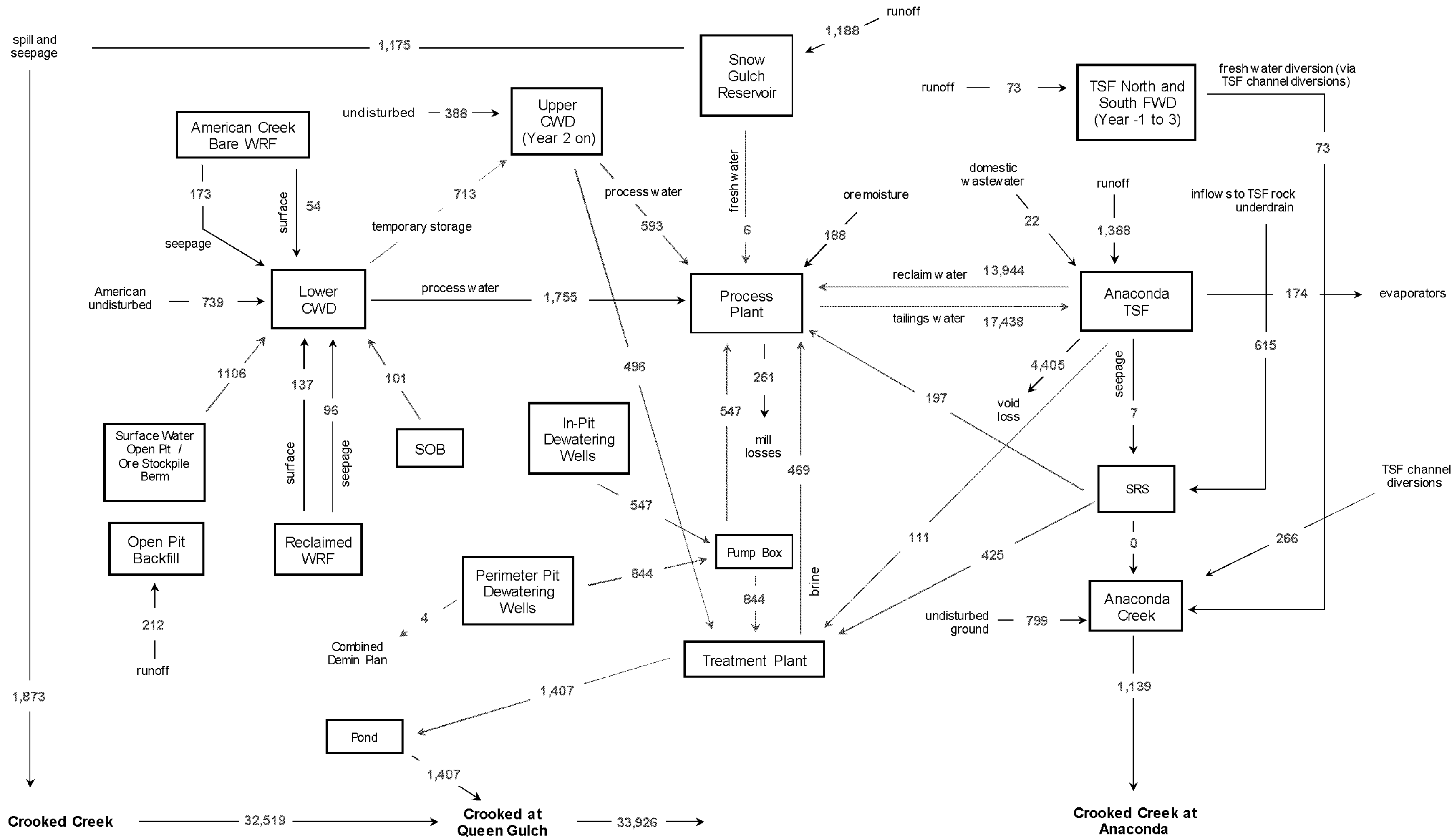
Table 4-5. Water balance schematic figures for excess discharge scenario.

Year	10^{th} percentile	50^{th} percentile	90^{th} percentile
2	Figure 4-6a	Figure 4-6b	Figure 4-6c
5	Figure 4-7a	Figure 4-7b	Figure 4-7c
15	Figure 4-8a	Figure 4-8b	Figure 4-8c
25	Figure 4-9a	Figure 4-9b	Figure 4-9c



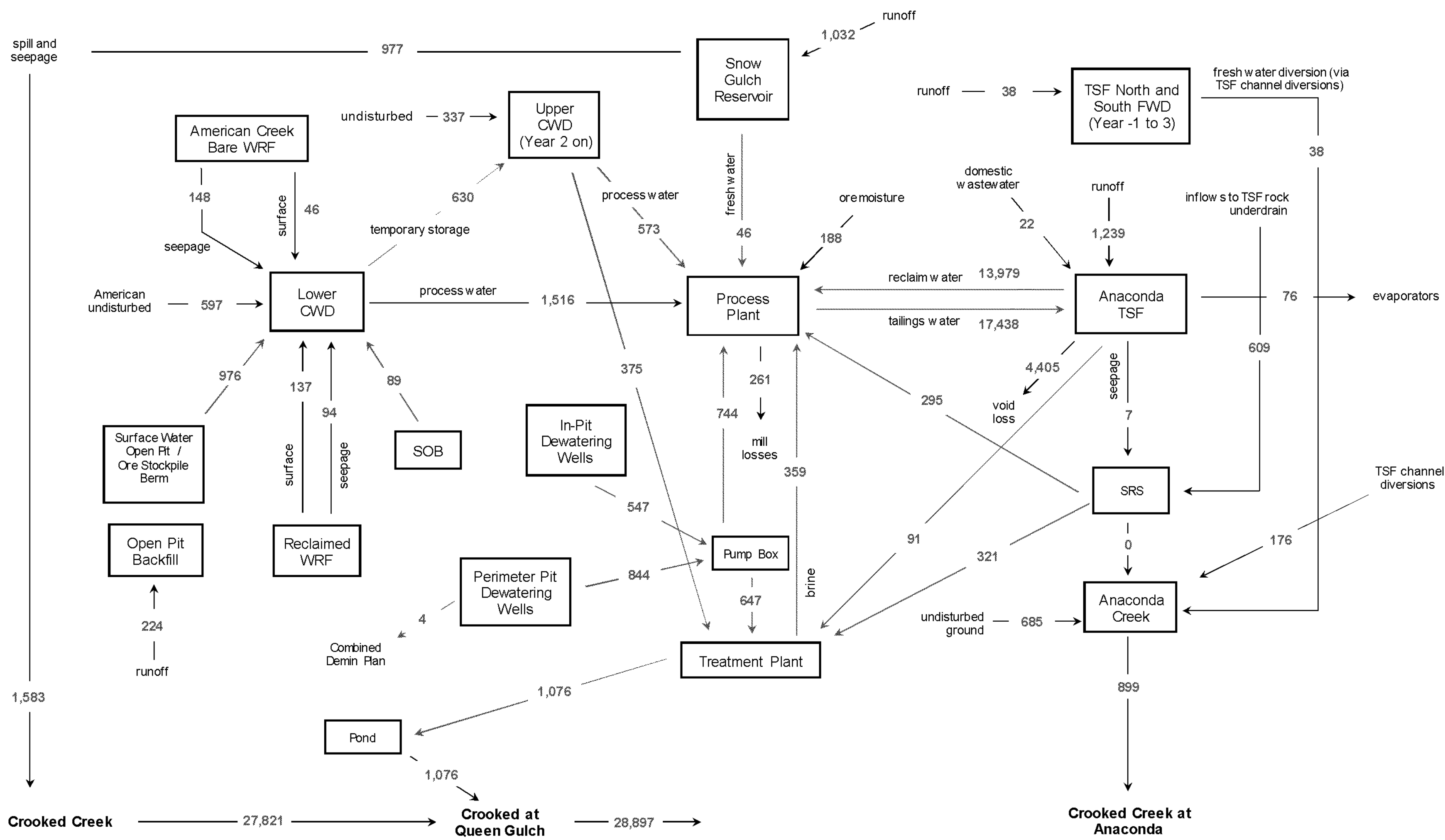
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-3. Donlin Gold schematic water balance for Years 2 to 27 of Operations (average precipitation scenario).



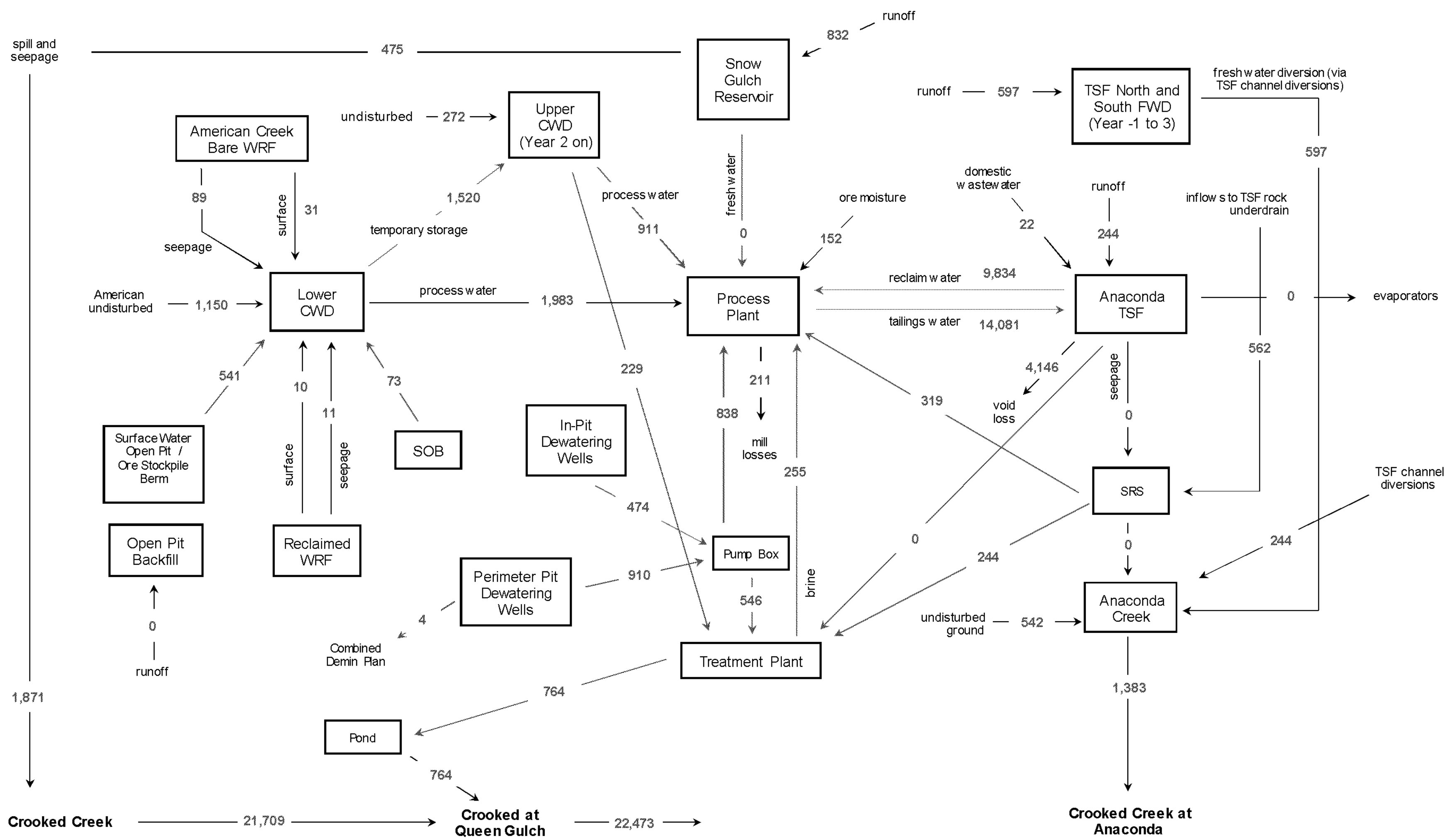
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-4. Donlin Gold schematic water balance for Years 2 to 27 of Operations (above average precipitation scenario).



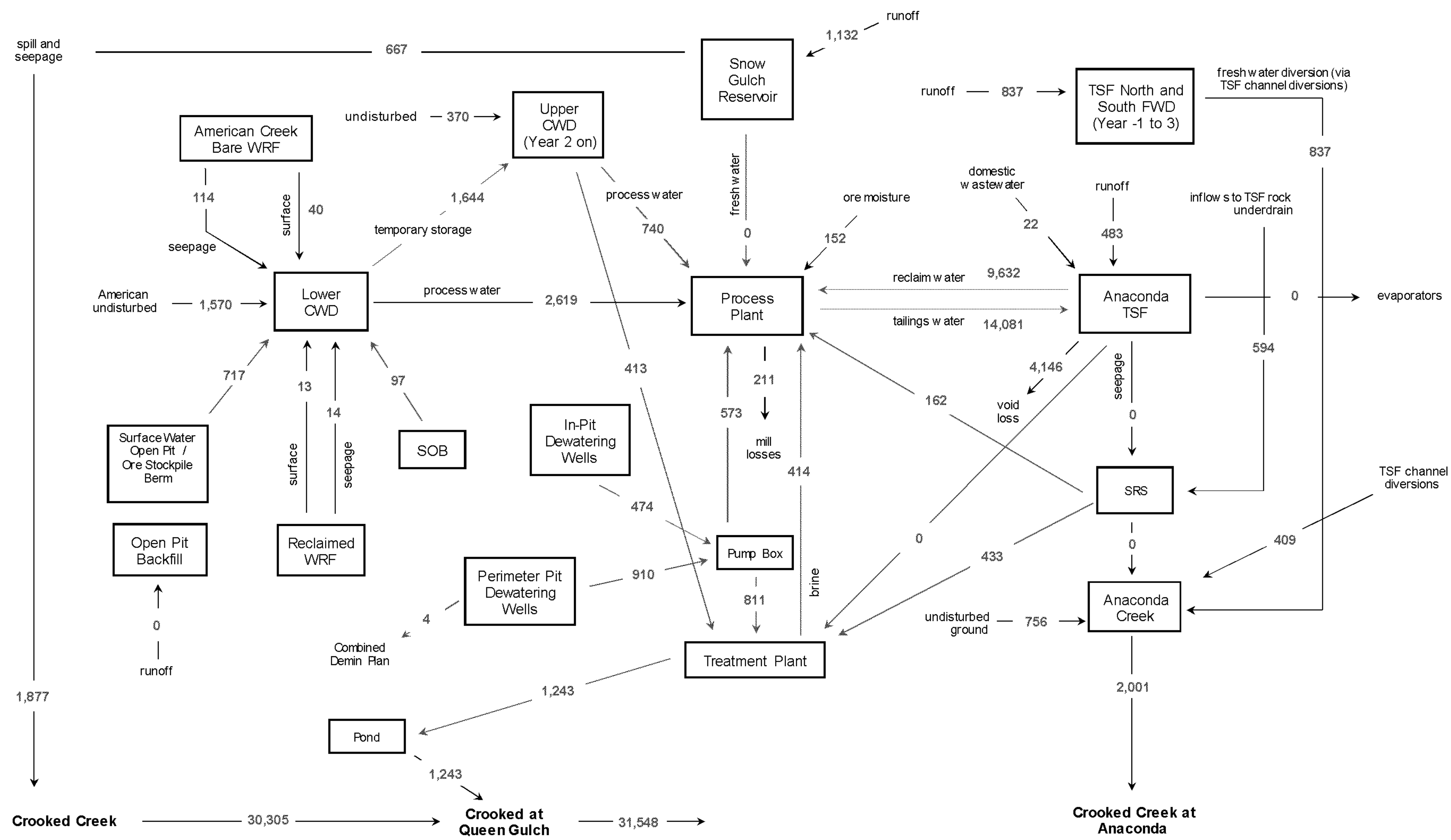
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-5. Donlin Gold schematic water balance for Years 2 to 27 of Operations (below average precipitation scenario).



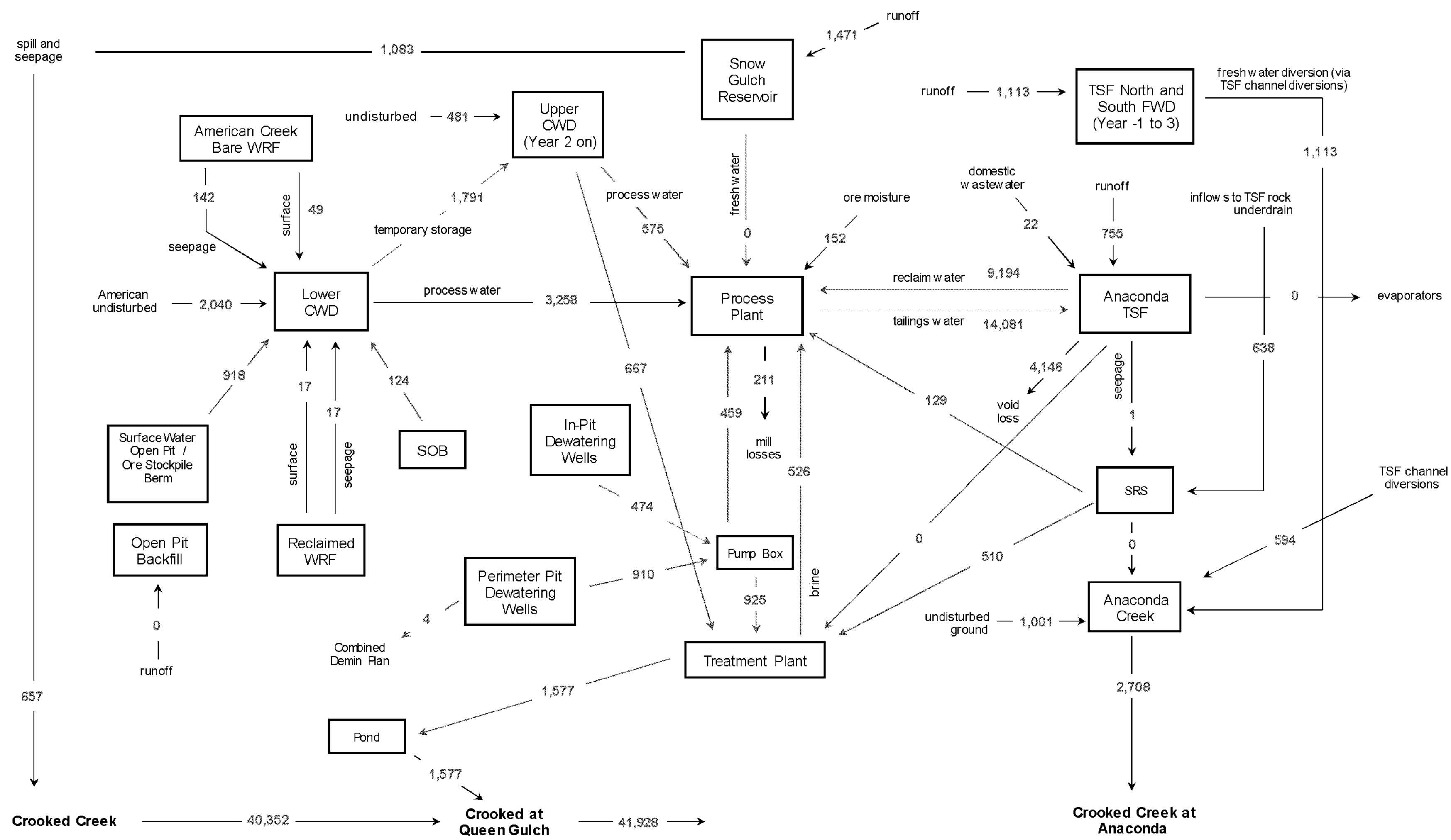
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-6a. Donlin Gold Schematic Water Balance – Year 2, 10th Percentile



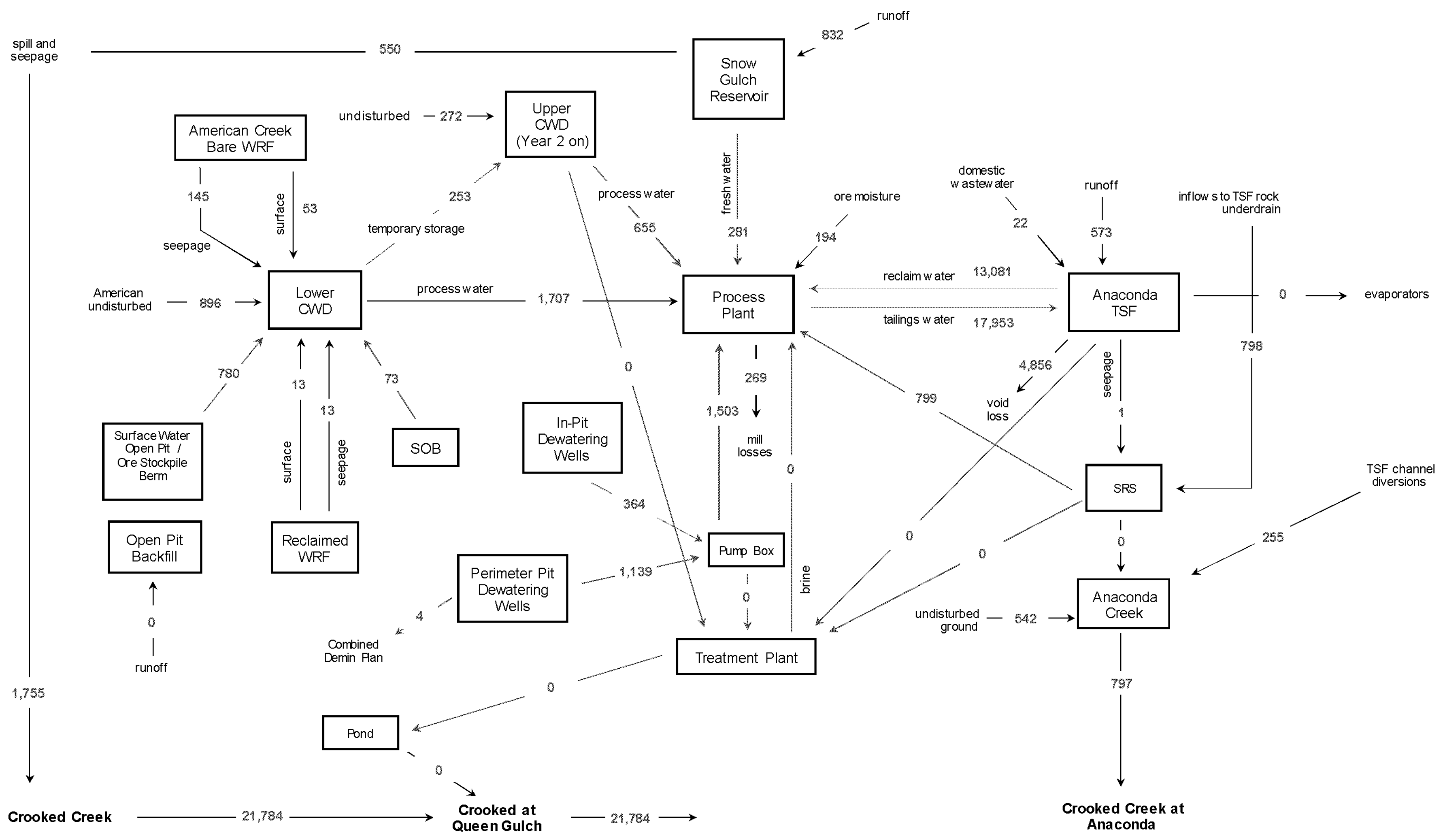
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-6b. Donlin Gold Schematic Water Balance – Year 2, 50th Percentile



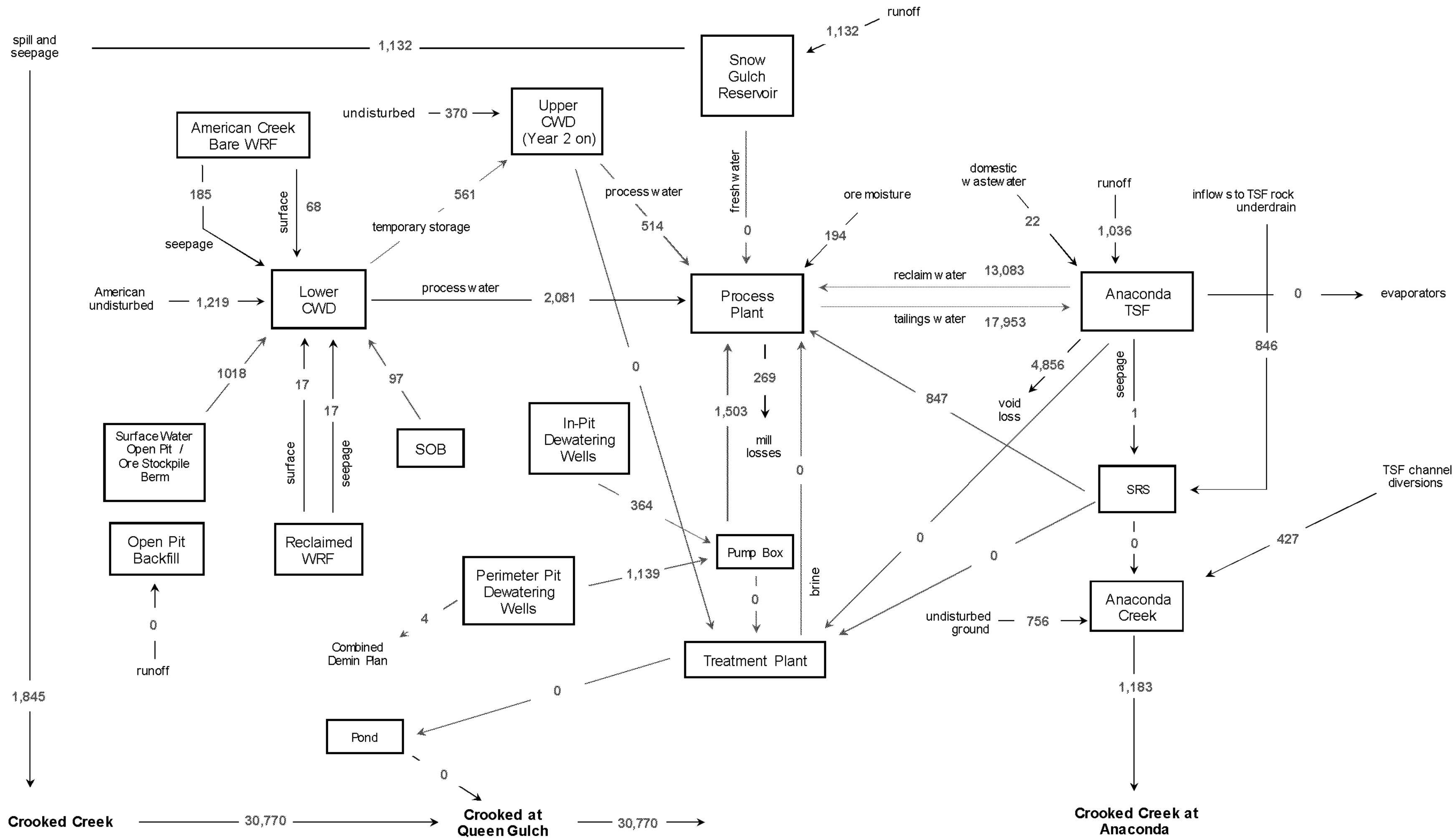
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-6c. Donlin Gold Schematic Water Balance – Year 2, 90th Percentile



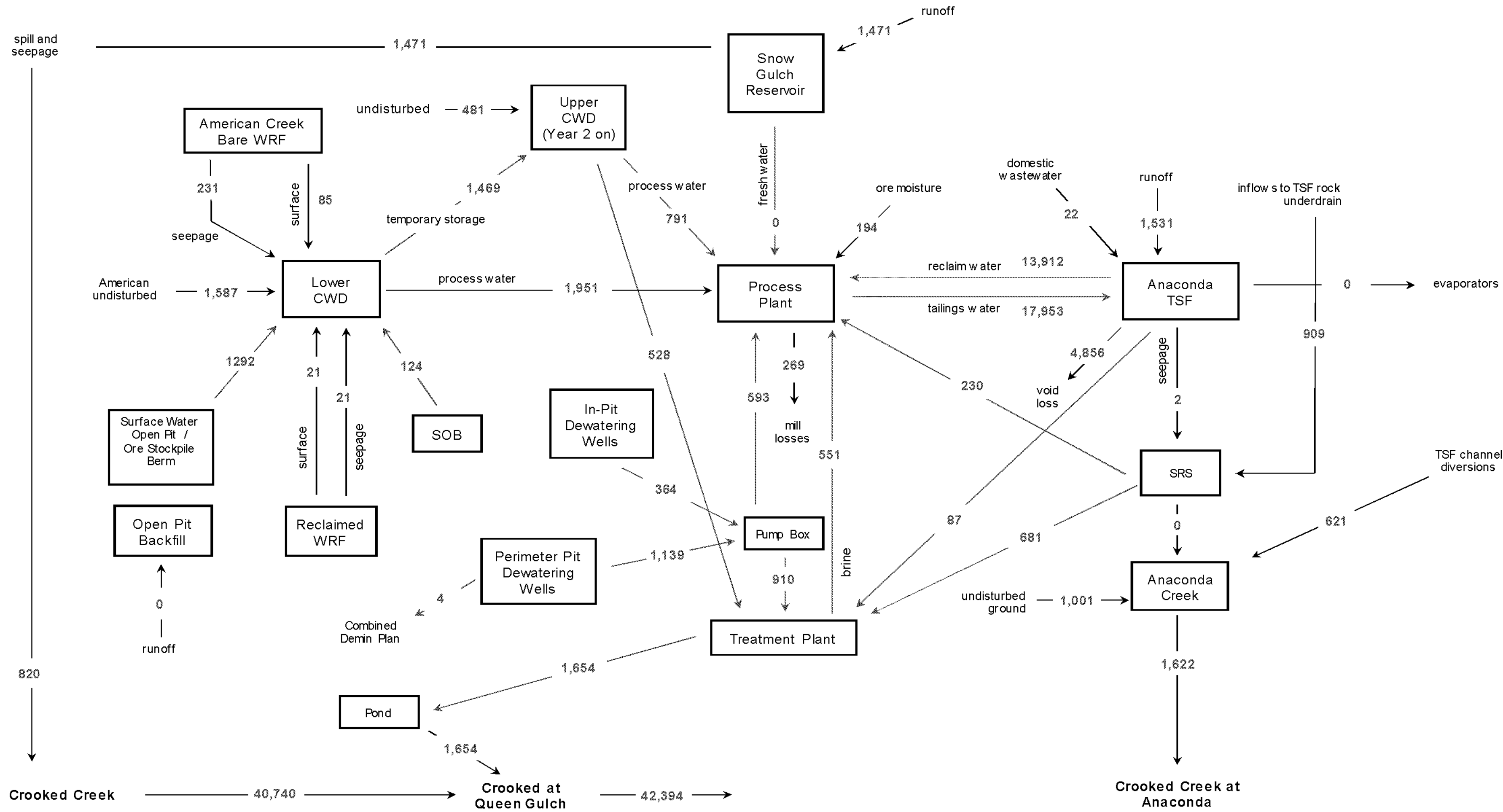
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-7a. Donlin Gold Schematic Water Balance – Year 5, 10th Percentile



Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

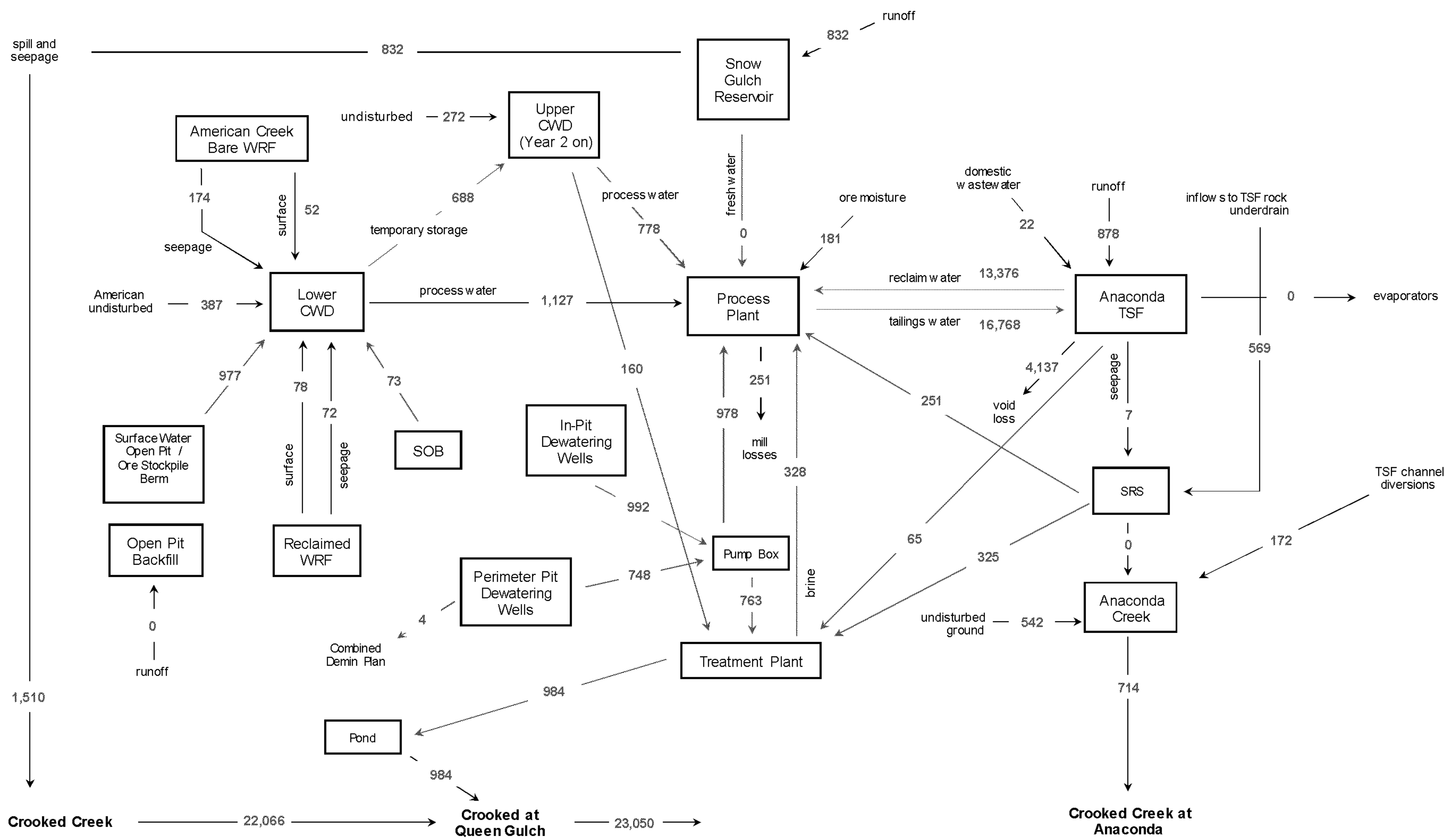
Figure 4-7b. Donlin Gold Schematic Water Balance – Year 5, 50th Percentile



Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

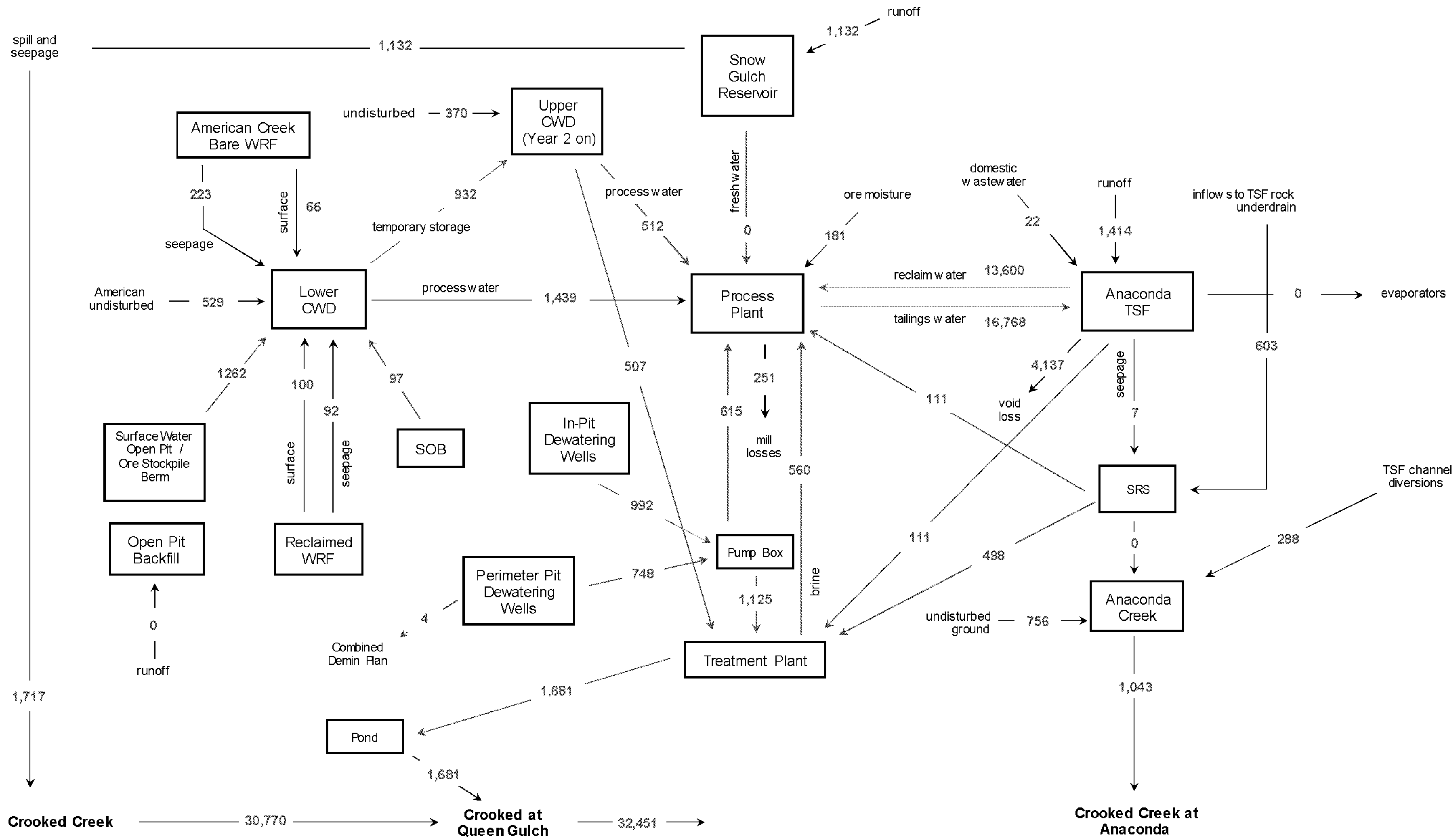
Figure 4-7c. Donlin Gold Schematic Water Balance – Year 5, 90th Percentile

ED_002038A_00000490-00033



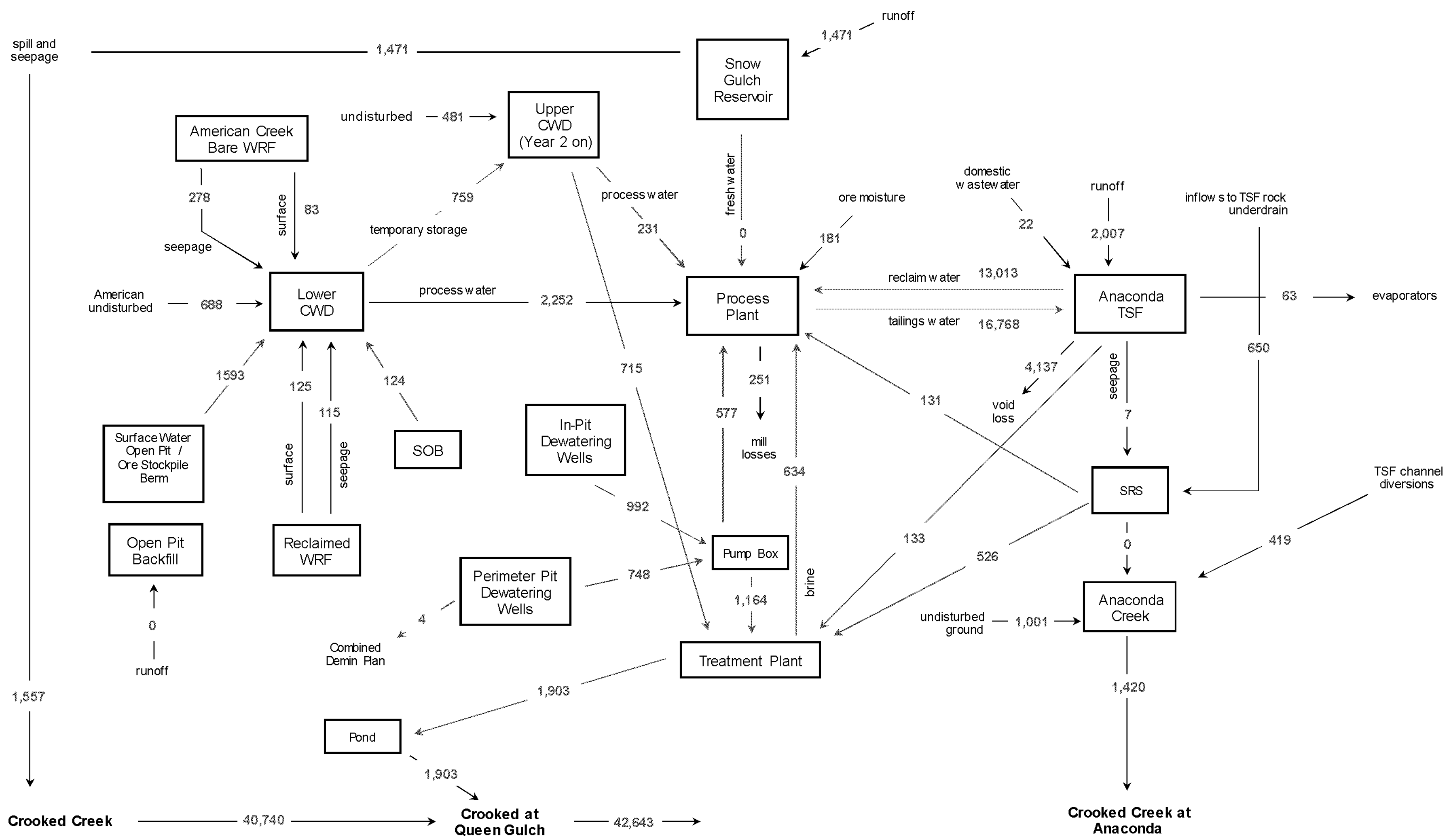
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-8a. Donlin Gold Schematic Water Balance – Year 15, 10th Percentile



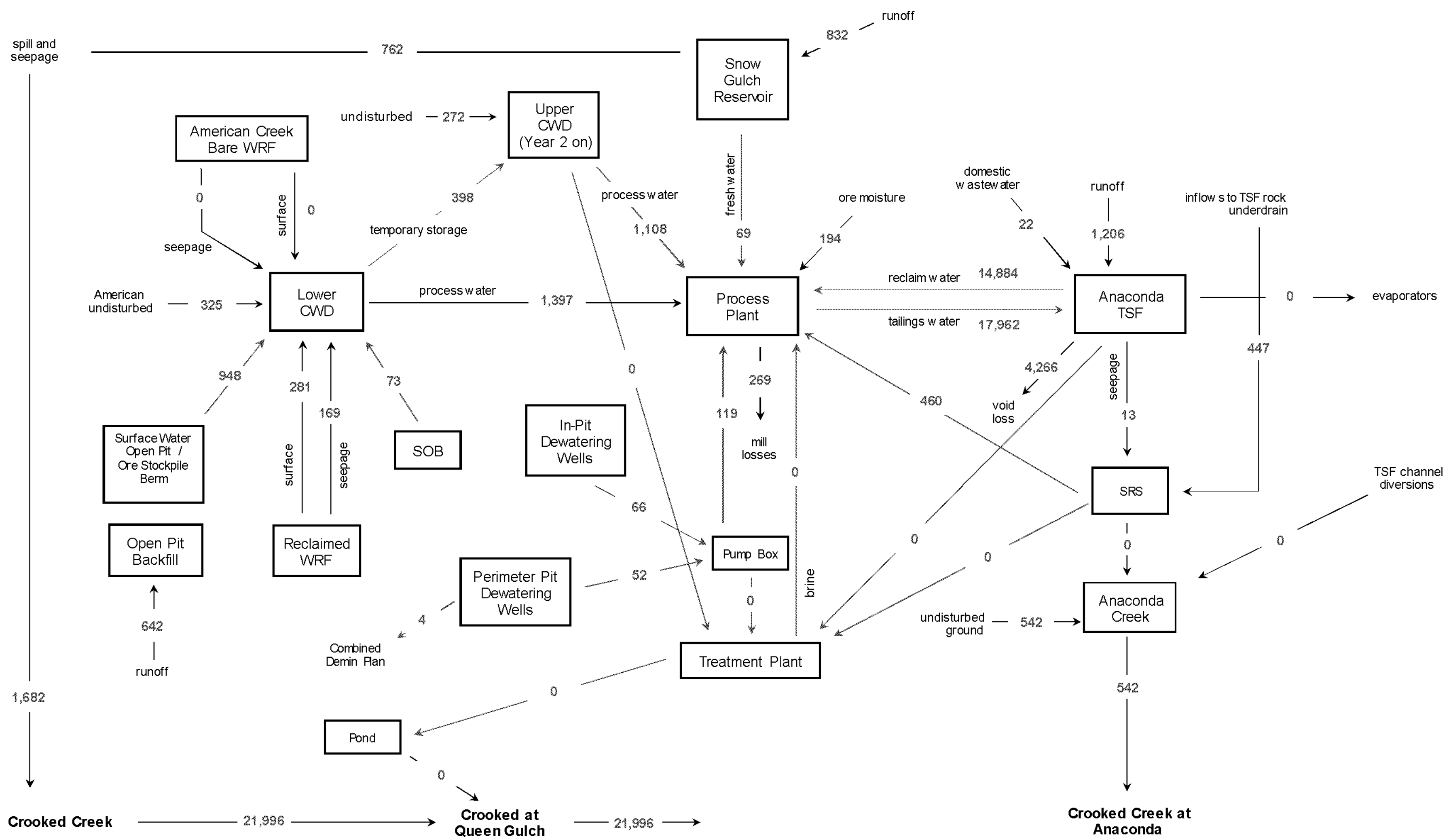
Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-8b. Donlin Gold Schematic Water Balance – Year 15, 50th Percentile



Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

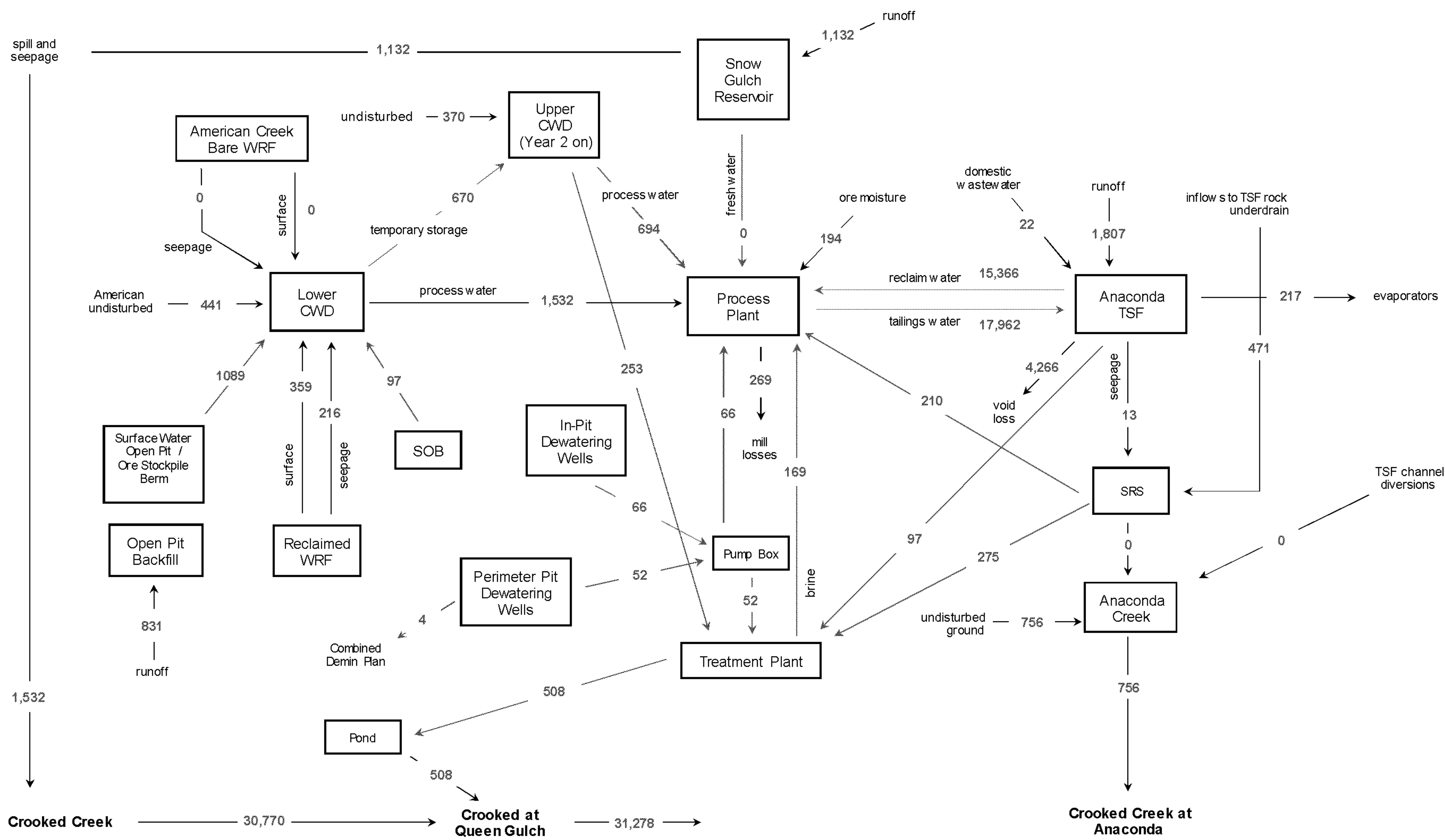
Figure 4-8c. Donlin Gold Schematic Water Balance – Year 15, 90th Percentile



Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

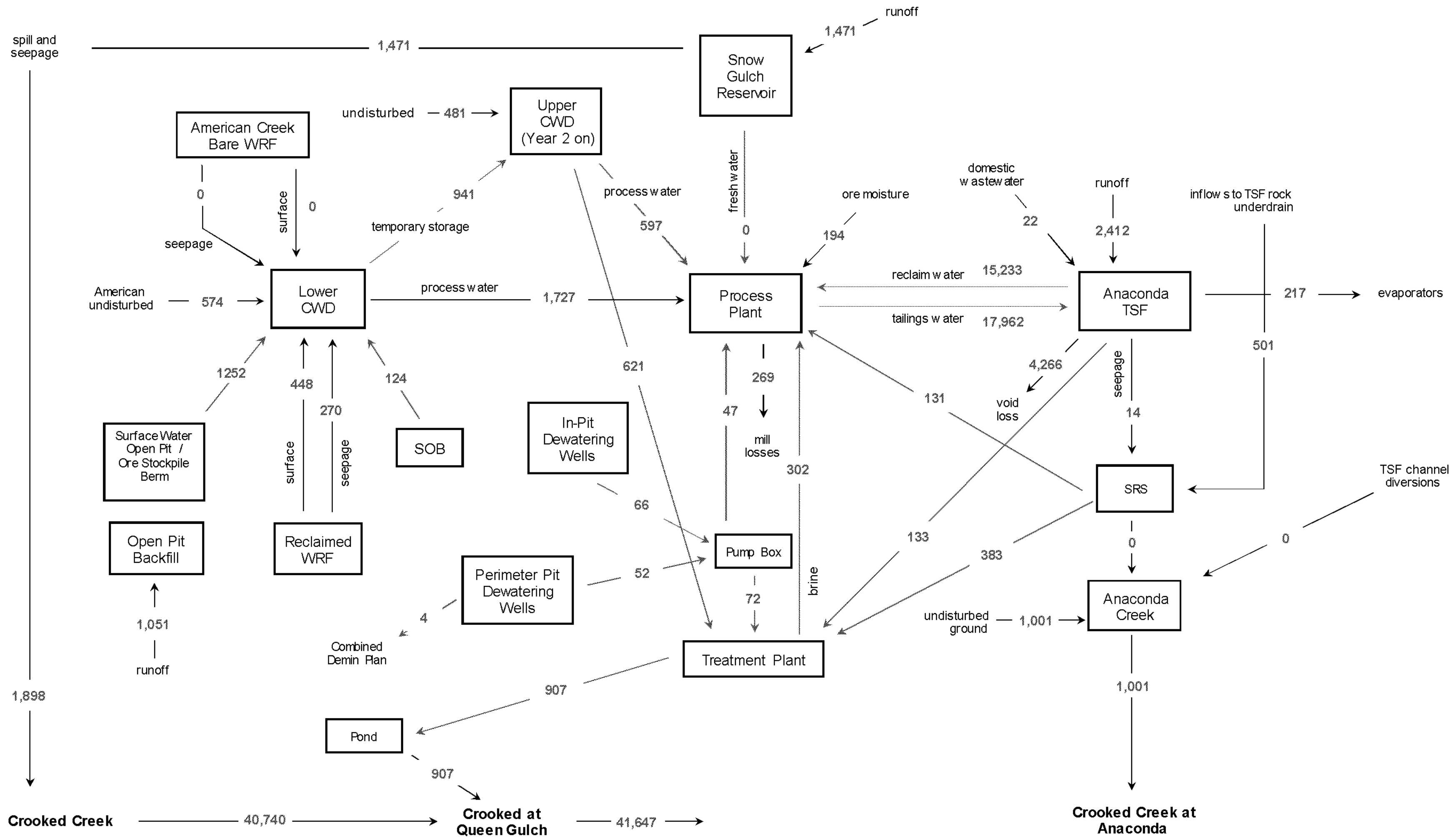
Figure 4-9a. Donlin Gold Schematic Water Balance – Year 25, 10th Percentile

ED_002038A_00000490-00037



Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-9b. Donlin Gold Schematic Water Balance – Year 25, 50th Percentile



Note: Red arrows denote pumping routes. Values shown are in gpm.
Note that all nodes do not balance, in particular the contact water dams and fresh water dam. These nodes do not balance as the dams either start with or end with a surplus of water.

Figure 4-9c. Donlin Gold Schematic Water Balance – Year 25, 90th Percentile

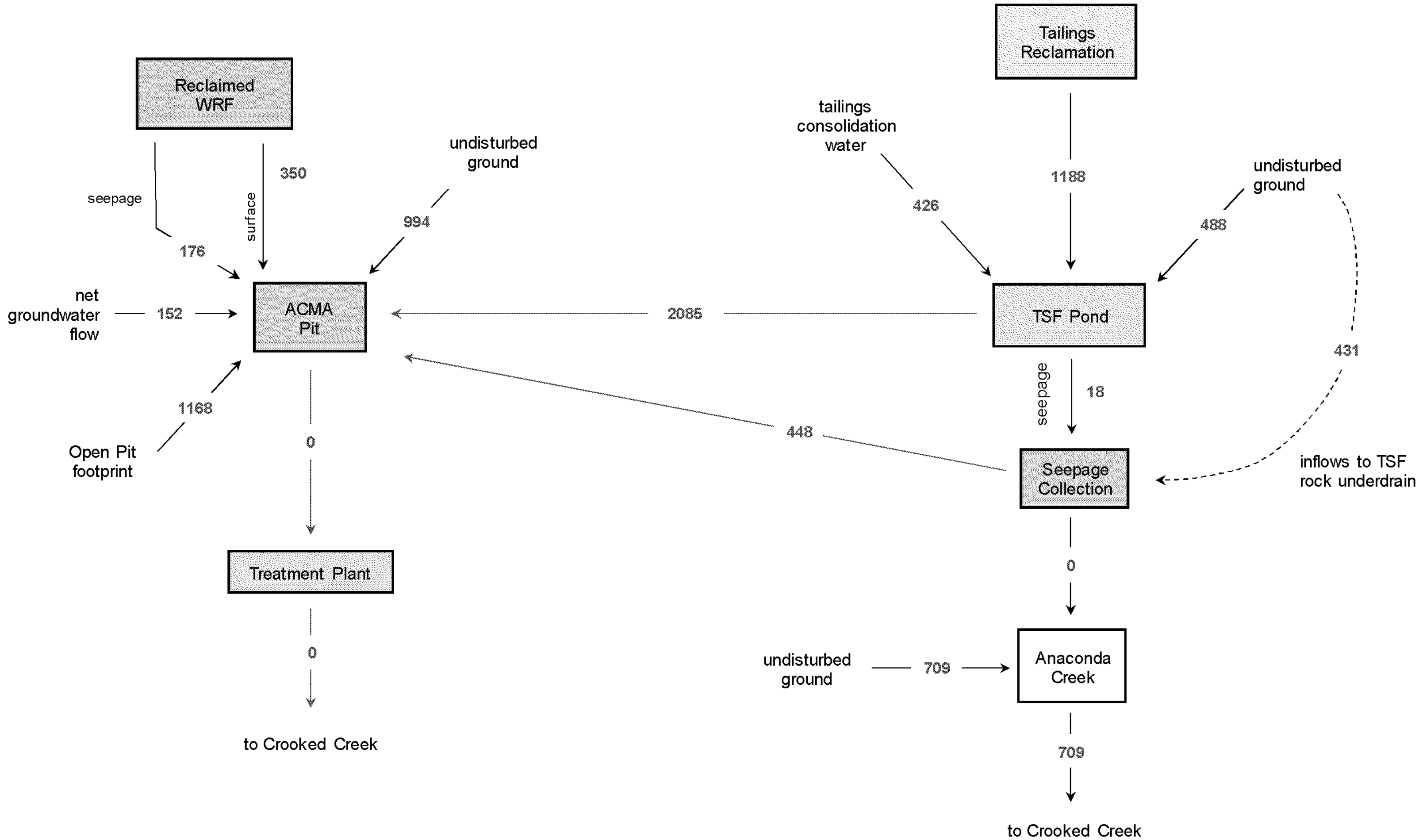
5. WATER RESOURCES MANAGEMENT PLAN – CLOSURE

For the 2012 WRMP, it was assumed that runoff reporting to the SRS would not have suitable chemistry for discharge to groundwater or surface water throughout the Post-Closure period. However, with the closure plan for the TSF that involves placement of a vegetated cover and subsequent draining of tailings pore water, it is now assumed that after Closure Year 52 SRS water will be consistent with natural conditions and suitable for discharge (see BGC, 2014b). However, monitoring to demonstrate seepage water quality would continue for both the SRS pond and collection wells until analytical results indicate acceptable chemistry for discharge. If the seepage water is not suitable for discharge, it would continue to be pumped to the pit lake.

Figures 5-1 through 5-4 show water balance schematics for the Closure and Post-Closure period based on the modified WMS. These figures represent:

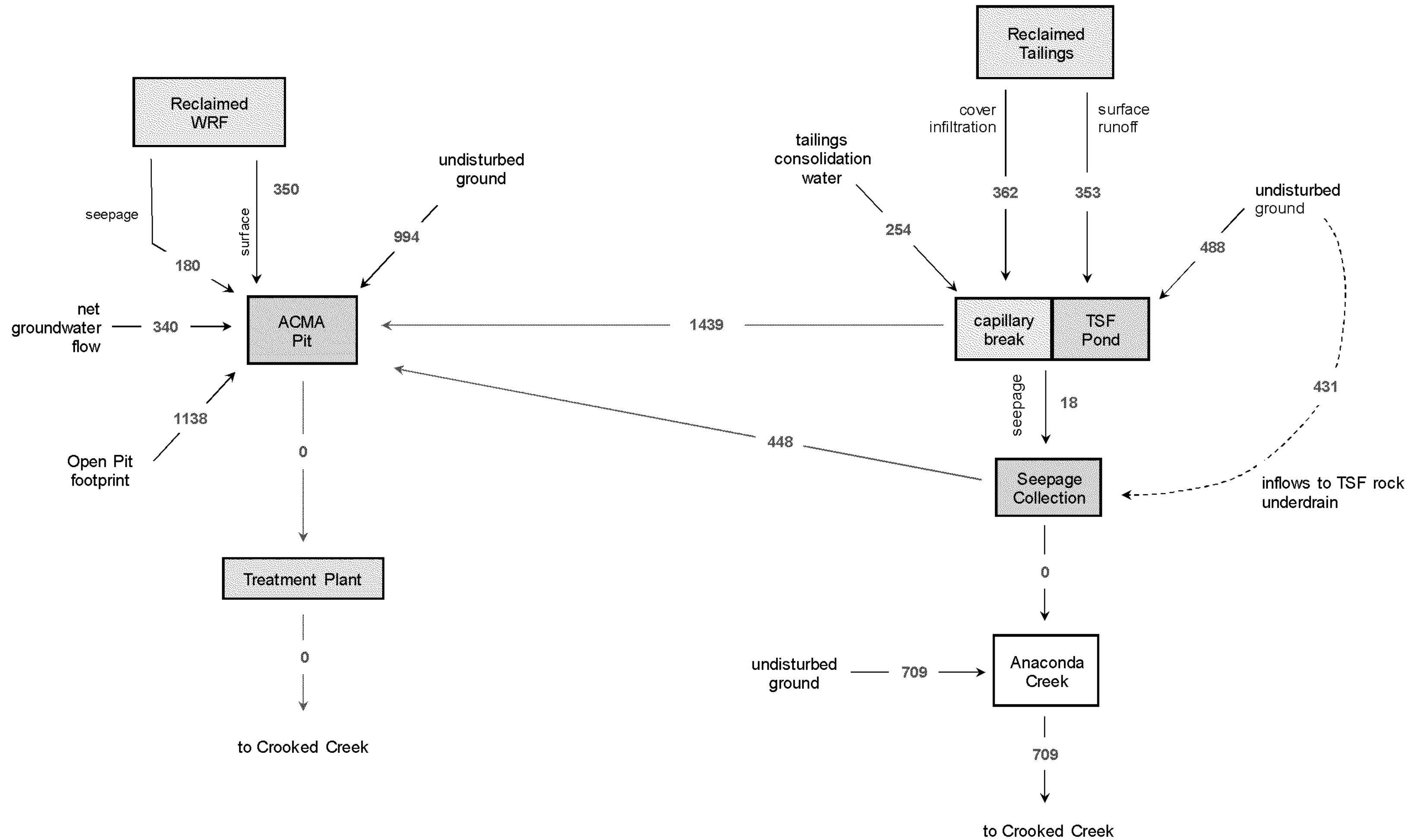
- Years 1 to 5 – closure of TSF facility, all TSF water pumped to ACMA Pit (Figure 5-1);
- Years 6 to 10 – monitoring of TSF pond water quality, all runoff from the reclaimed TSF continues to be pumped to ACMA Pit (Figure 5-2);
- Years 11 to 51 – TSF pond water is released to Crevice Creek (surface runoff), but TSF seepage water and consolidation/infiltration water is still captured and sent to ACMA Pit (Figure 5-3); and
- Year 52 on – no capture of TSF seepage water, tailings consolidation complete, and treatment of pit water commences (Figure 5-4).

TSF impoundment volume pumped to ACMA Pit at end of Operations 8,190 acre-ft
Runoff accumulated in open pit backfill during Operations 8,910 acre-ft



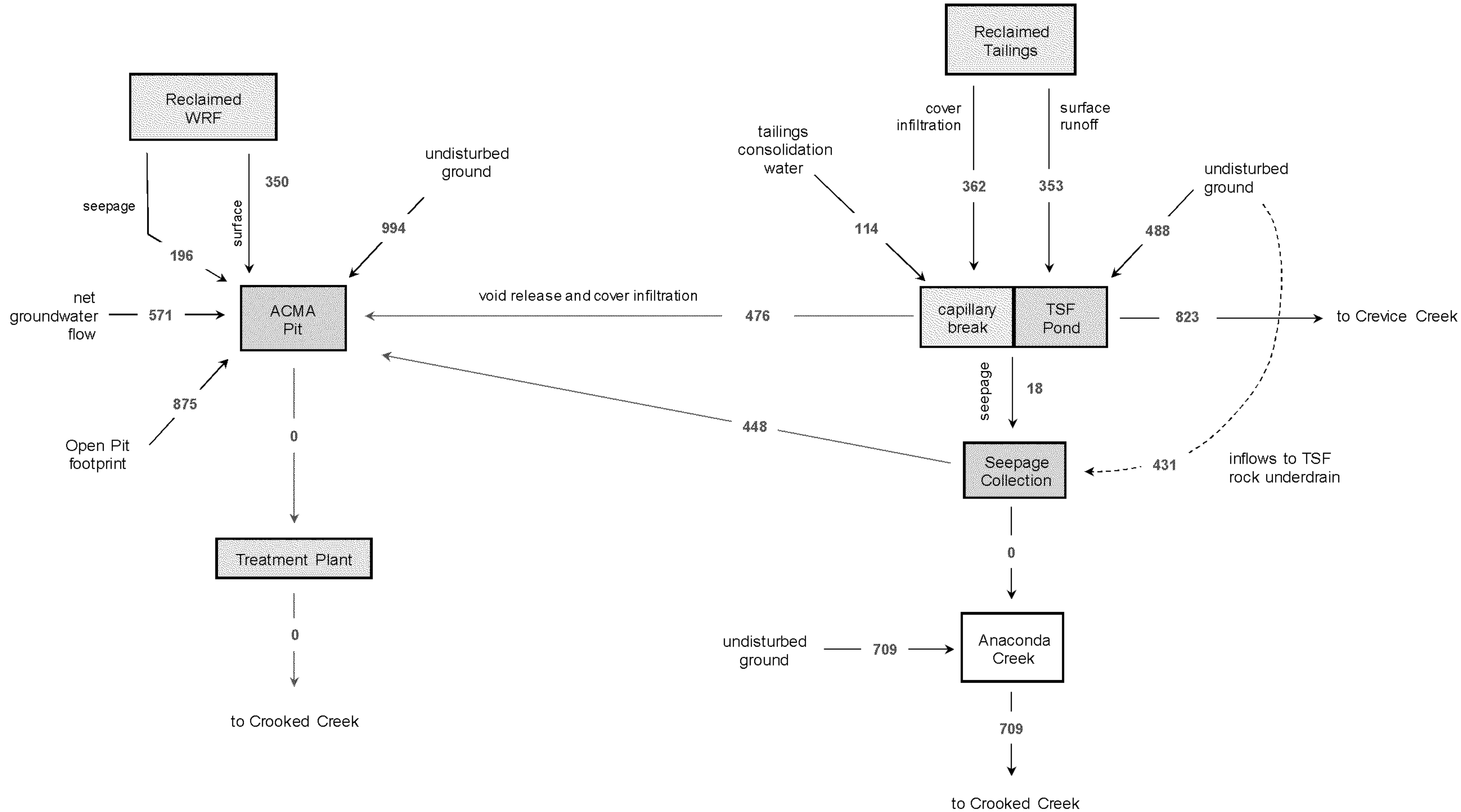
Note: Values (gpm) shown are averaged over Years 1 to 5 of closure. Red arrows denote pumping routes.

Figure 5-1. Donlin Creek Schematic Water Balance Closure Conditions – Year 1 to 5



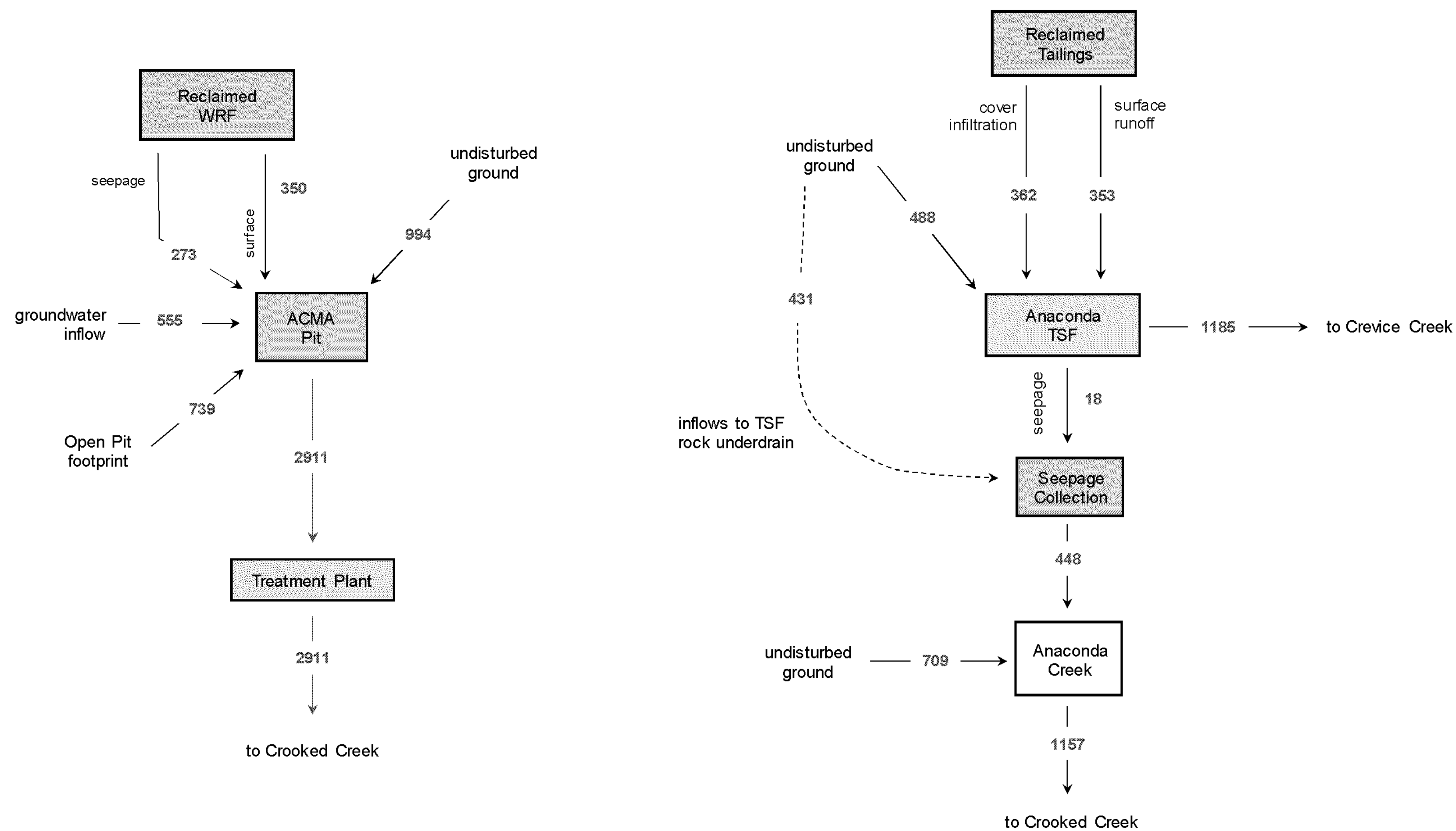
Note: Values (gpm) shown are averaged over Years 6 to 10 of closure (the TSF pond monitoring period). Red arrows denote pumping routes.

Figure 5-2. Donlin Creek Schematic Water Balance Closure Conditions – Year 6 to 10



Note: Values (gpm) shown are averaged over Years 11 to 51 of closure (tailings consolidation water and TSF seepage water continue to be collected and pumped to ACMA Pit). Red arrows denote pumping routes.

Figure 5-3. Donlin Creek Schematic Water Balance Closure Conditions – Year 11 to 51



Note: Values (gpm) shown are averaged over Years 52 to 200 of closure. Red arrows denote pumping routes.

Figure 5-4. Donlin Creek Schematic Water Balance Closure Conditions – Year 52 On

CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of Donlin Gold. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

As a mutual protection to our client, the public and ourselves, all documents and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this document or any data, statements, conclusions or abstracts from or regarding our documents and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending BGC's written approval. If this document is issued in an electronic format, an original paper copy is on file at BGC and that copy is the primary reference with precedence over any electronic copy of the document, or any extracts from our documents published by others.

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING INC.
per:

STATE OF ALASKA
49TH
HAMISH WEATHERLY
REGISTERED PROFESSIONAL GEOLOGIST

12 JUNE 2015

Hamish Weatherly, M.Sc., CPG
Principal Hydrologist

Reviewed by:

Trevor Crozier, M.Eng., P.Eng., Principal Hydrogeological Engineer

HW/TC/sah

REFERENCES

Applied Water Treatment Solutions Inc. (2014) Conceptual Design Options for Water Treatment Plant. Draft report prepared for Donlin Gold LLC, July 7, 2014.

BGC Engineering Inc. (2011a) Donlin Creek Tailings Storage Facility Design - Final. Report DC11-025 prepared for Donlin Creek LLC, July 22, 2011.

BGC Engineering Inc. (2011b) Donlin Creek Gold Project Feasibility Study Update II, Water Management Plan - Final. Report DC11-032 prepared for Donlin Creek LLC, July 22, 2011.

BGC Engineering Inc. (2014a) Donlin Gold Project, Numerical Hydrogeologic Model. BGC Document No. ER-0011165.0029 A. Report prepared for Donlin Gold. July 2014.

BGC Engineering Inc. (2014b) Water Resources Management Plan Interim Update, July 2014. BGC Document No. EN-0011178.0040. Memorandum prepared for Donlin Gold. July 2014.

Donlin Gold (2015) Water Quality Estimates. Report in preparation.

Geo-Slope (2007) Slope/W version 6.0. Modeling with SLOPE/W – An Engineering Methodology. Geo-Slope International Ltd.

Giroud JP and Bonaparte R (1989) Leakage through liners constructed with geomembrane liners-parts 1 and II and technical notes. Geotextiles and Geomembranes, 8(1), 27-67, 8(2), 71-111, 8(4), 337-340.

Giroud JP (1997) Equations for calculating the rate of liquid migration through composite liners due to geomembrane defects, 4 (3-4) 335-348.

Hatch (2015a) Donlin Gold – Advanced Water Treatment, Advanced Water Treatment Options Report. Report prepared for Donlin Gold. May 8, 2015.

Hatch (2015b) Donlin Gold: Advanced Water Treatment Options, Process Design Basis – Process Plant Water Management Philosophy. Report prepared for Donlin Gold. May 8, 2015.

Schroeder PR, Dozier TS, McEnroe BM, Sjostrom JW (1994) The hydrogeologic evaluation of landfill performance (HELP) model, engineering documentation for version 3, U.S. Environmental Protection Agency, Cincinnati, OH, September 1994.

SRK Consulting (US) Inc. (2012) Water Resources Management Plan, Donlin Gold Project. Report prepared for Donlin Gold, July 2012.